#99
SOY BEAN OIL HYDROGENATED VOL I

U27

VOLUME 1

GRAS MONOGRAPH SERIES
SOY BEAN OIL, HYDROGENATED

prepared for
THE FOOD AND DRUG ADMINISTRATION
DEPARTMENT OF HEALTH, EDUCATION
AND WELFARE

DECEMBER 27, 1973

This publication was prepared under Contract Number FDA 72-100
with the Public Health Service, Food and Drug Administration,
Department of Health, Education, and Welfare

prepared by

Tracor Jitco, Inc.

Table of Contents

SUMMARY

Description and Specifications

Soybean oil is the oil expressed from the seeds of the soybean or soya bean (*Glycine max* (L.) or *G. soja*); these are all synonyms. Its composition varies according to soil, climate, and other conditions of plant growth (022,125,134). In general the fatty acids (FA) are present mostly as triglycerides; about one-half of the FA are polyunsaturated (PUFA) and 90% of the PUFA are diene. Soybean oil also contains small amounts of sterols including cholesterol.

The purpose of hydrogenation is to elaborate a stable, palatable product of suitable plasticity; chemically, the aim is to part-saturate polyene, but not monoene, chains (013). Both the process and the products of hydrogenation are variable, and hydrogenated soybean oils are never more than partly hydrogenated (081,167,245,305). The proportion of double bonds left unsaturated is reflected by the iodine number. Hydrogenation also changes the FA composition in other ways -- not very predictably in most cases (013,167,305). Manufacturers tend to patent particular procedures to protect products with particular handling characteristics (046,295,299,314,371). So hydrogenated soybean oils include a wide range of chemically different oils that vary according to source and subsequent treatment (166,250). No complete analysis of any one sample was found in the literature.

The most important food uses of hydrogenated soybean oil in the United States are in margarines and shortenings (Tables 14 & 15). However, there is no standard of identity for hydrogenated soybean oil, and the nearest approach is the Codex Alimentarius Recommended International Standard for Edible Soya Bean

are "all only potential effects" that can be "controlled by the use to which the oil is put."

Theoretically peroxides can give rise to epoxides, which can be carcinogenic (158). No studies were found to suggest that this might occur *in vitro* or *in vivo* with hydrogenated soybean oil.

Long Term Studies

No long term studies were found. A series of patients (47 years average) fed soybean oil, not hydrogenated, showed no difference from the controls in the relapse rate for myocardial infarctions (351). The controversial question of the general relationships of saturated/unsaturated fats, cholesterol, and atherogenesis was considered to be outside the scope of a monograph restricted to hydrogenated soybean oil; some reports involving soybean oil are mentioned in the section on Metabolism.

A review by Scott (367) on the geography and incidence of selenium deficiency in the United States is summarized in view of the current debate about whether excesses of selenium are carcinogenic. Scott concludes otherwise, and emphasizes that selenium is probably an essential nutrient in the range 0.1-0.3 ppm, although toxic in the range 2-10 ppm. Absence of selenium affects the activity of vitamin E, and the bioavailability of selenium in soybean meal feeds is relatively low (367).

Special Studies

No tolerances have been set by the Food and Drug Administration for levels of residues from chlorinated hydrocarbon pesticides in edible oils; such tolerances have been set, however for seeds such as soybeans (147). Gooding *et al.* (147) and Smith *et al.* (378) concluded that all such residues would be removed by normal refining, hydrogenation, and post-hydrogenation treatment of the oils. Stout

et al. (390), however, have denied this claim and have pointed to some of the data of Smith et al. (378) as supporting their denial. The debate revolves round the temperature of final deodorization, and is not yet concluded.

Methods for detecting accidental contamination of oils by polychlorinated biphenyls remain imperfect (043), and no reports on their elimination were found.

Breakdown and Metabolism

Oxidation results in "off" flavors (082,164,326), and hydrogenation generates "hardening" flavors that are removed by further refining. The latter arise from small amounts of free or bound aldehydes, especially 6-trans-nonenal, which can sometimes be detected at a dilution of 0.3 ppb (230,294) (see Description section). Kawada et al. (228) emphasized that the volatile products of hydrogenation differ from those of autoxidation, but no studies on breakdown products of autoxidizing hydrogenated soybean oil were found.

No reports were found to suggest that the digestion, absorption, metabolism, or metabolic effects of hydrogenated soybean oil might differ from those of other dietary fats, or might affect the growth or survival time of man or experimental animals differently from other dietary fats (291,397). Many reports indicated that the distribution of the various FA in body fats tends to reflect that in the diet, taking into account the fact that some FA are readily metabolized or liable to inhibit the metabolism of other FA. This was shown by Beare (042), Neudorffer and Lea (318), Imaichi et al. (200), and Hølmer and Aaes-Jørgensen (189) using complete fats or oils; and by Aaes-Jørgensen (004) and Mohrhauer and Holman (309,310) using isolated FA as sole or principal sources of fat intakes. Van der Steur (412) pointed

relevance to atherosclerosis does not emerge from data (247,351,384) reviewed in the monograph.

Drug Interactions

No reports were found on soybean oil and drug interaction.

Consumer Exposure

In 1970, 8261 million pounds of soybean oil were produced in the United States, of which 2182 million pounds went into shortenings (total production 3599 million pounds) and 1410 million pounds into margarines (total production 1794 million pounds). The soybean oil contributions to shortenings and margarine were slightly less in 1971, but in all have approximately quadrupled since 1949 (404). No data are given on hydrogenated soybean oils, but the section on Description indicates that much of this oil is partly hydrogenated.

No data on hydrogenated soybean oils are given in the NAS NRC Comprehensive GRAS Survey (137), and no estimate can be made from the survey findings as to the extent of per capita exposure. Nevertheless the tables referring to "Soybean Oil" are abstracted in this monograph (Table 14 and 15).

CHEMICAL INFORMATION

I. Nomenclature

A. Common names: Soybean oil (hydrogenated), hydrogenated soybean oil, hydrogenated soya bean oil, partly or partially (sic) hydrogenated soybean or soya bean oil. Derived from the seeds of *Glycine max* (L.) Merr. (*G. soja*).

B. Chemical names: None for the entire product, which is a mixture.

C. Trade names: Same as common names.

D. Chemical Abstract Services Unique Registration Number:

MX 8016 70 4

NOTE: Because hydrogenation is always incomplete and variable, and the results are hard to define precisely, much of the available research information concerns unhydrogenated soybean and analogous oils. Some of this information is included in this monograph as supporting data.

II. Empirical Formula

The composition of fresh soybean oil varies widely according to geography, soil, climate, and seasonal weather. Data claimed to be typical but not average are given in Table 1, adapted from Altman and Dittmer (022), and in Table 2, adapted from Fineberg and Johanson (134). Different data are shown in Table 3, adapted from Erlandsen (125).

The fatty acids (FA) are present mostly as triglycerides, with a small but uncertain fraction as free fatty acids (FFA). About one-half of the FA are polyunsaturated fatty acids (PUFA), and about 90% of the PUFA have two double bonds. The unsaponifiable fraction contains mainly sterols, including cholesterol.

Hydrogenation results in chemical changes that are even more variable. According to Ackman *et al.* (013), "The partial hydrogenation of fats and oils to produce a stable, palatable product of suitable plasticity results in the formation of new, structurally altered fatty acids which in most cases differ chemically from familiar natural products." Table 4 shows the variable effects of hydrogenation reported from four different laboratories. The FA composition of a partly hydrogenated mixture of vegetable oils that included soybean oil has been described by Kuemmel and Chapman (248).

Composition in terms of glycerides is altered accordingly (see Table 4, upper left) but is rarely reported. Handschumaker *et al.* (166) observed dipalmito and distearo glycerides after hydrogenation of a mixture that included soybean oil.

Table 1

Typical Composition of Fresh Soybean Oil*

Concentration g/100 g total fatty acids	Identity of Fatty Acid Components: FASEB Serial # Table 42	Name	Empirical formula	Common Name of Components: FASEB Serial # Table 43	Name
Saturated Fatty Acids					
0.2	(12)	Dodecanoic acid	$C_{12}H_{24}O_2$	(257)	Lauric acid
0.1	(14)	Tetradecanoic acid	$C_{14}H_{28}O_2$	(258)	Myristic acid
9.8	(16)	Hexadecanoic acid	$C_{16}H_{32}O_2$	(259)	Palmitic acid
2.4	(18)	Octadecanoic acid	$C_{18}H_{36}O_2$	(260)	Stearic acid
0.9	(20)	Eicosanoic acid	$C_{20}H_{40}O_2$	(261)	Arachidic acid
Unsaturated Fatty Acids - Monoethenoic					
0.1	(87)	Tetradecenoic (Tsuzuic) acid	$C_{14}H_{26}O_2$	(262)	Tetradecenoic acid
0.4	(95)	cis-9-Hexadecenoic acid	$C_{16}H_{30}O_2$	(263)	Palmitoleic acid
28.9	(117)	cis-12-Octadecenoic acid	$C_{18}H_{34}O_2$	(264)	Oleic acid
Unsaturated Fatty Acids - Dienoic					
50.7	(159)	cis-9,cis-12-Octadecadienoic acid	$C_{18}H_{32}O_2$	(265)	Linoleic acid
Unsaturated Fatty Acids - Trienoic					
6.5	(180)	cis-6,cis-9,cis-15-Octadecatrienoic acid (γ)	$C_{18}H_{30}O_2$	(266)	Linolenic acid
	(191)**	cis-9,cis-12,cis-15-Octadecatrienoic acid (α)	$C_{18}H_{30}O_2$		
0.27%				(267)	Sterols

* Abstracted from K.S. Markley (Table 42) and R.P. Geyer (Table 43) in Altman and Dittmer (022).

** Linolenic acid is stated to have two isomeric forms (α and γ) with indistinguishable properties.

Table 2

Some Constants of Fresh Soybean Oil*

1. Extent of unsaturation (percent composition):	
Saturated	12.3 - 15
Monoenes	18.2 - 35
Dienes	44.5 - 57.2
Trienes	5.0 - 9
2. Acid chain lengths (percent composition):	
C_{12}	0.2
C_{14}	0 - 0.2
C_{16}	8.0 - 14.9
C_{18}	89 - 92
C_{20}	0 - 1
3. Iodine number	120 - 141
4. Saponification value	189 - 195
5. Unsaponifiables, percent	1.5 maximum
6. Free fatty acid content	"Reliable data unavailable"

* Adapted from Fineberg and Johansen (134)

Table 3

Another Typical Composition of Fresh Soybean Oil*

Fatty acid	Percent
Myristic	0.6
Palmitic	7.0
Stearic	5.8
Oleic	60.6
Linoleic	20.8
Linolenic	5.2

Constant	Value
Iodine number	129-137
Saponification value	192

* Adapted from Erlandsen (125)

Table 4

Compositional Changes in Oils by Hydrogenation

A. Gill and Yu (144) - Soybean oil

		Saturated Glycerides x	Per Cent Olein y	Linolin z	Fat A	Iodine Number Liquid Acids B
Run 6	(1)	28.5	53.5	18.0	78.2	114.1
	(2)	34.2	53.7	12.1	66.6	100.0
	(3)	43.4	54.5	2.1	50.2	92.7
Run 7	(1)	16.5	70.0	13.5	82.1	103.5
	(2)	39.0	56.2	4.8	56.6	97.3
	(3)	46.3	53.7	0.0	43.9	86.2
	(4)	47.5	52.5	0.0	40.5	80.3

B. DeJonge et al. (113) - Soybean oil

Analytical Results of Soya-bean Oil Hydrogenated with a Nickel (Nos. 1-5) or a Copper (Nos. 6-9) Catalyst

No.	Iodine value	Composition* (wt. %) C 18 : 3	C 18 : 2	C 18 : 1	C 18 : 0	C 16 : 0	*Trans* fatty acid content (wt. %)	S_{Le}
0†	132·3	8·0	52·0	24·0	4·0	11·5	0	--
1	120·0	4·5	44·5	35·0	5·5	12·0	6·5	2·5
2	111·4	4·0	37·5	39·5	5·0	12·0	12·0	2·0
3	103·7	3·0	32·0	45·0	6·0	12·0	19·5	2·0
4	98·5	2·0	28·0	52·5	6·0	11·0	23·0	2·0
5	91·7	0·7	23·5	58·0	7·0	11·0	25·5	2·5
6	127·0	5·6	53·0	26·0	4·0	11·5	4·0	8·0
7	120·8	2·7	51·5	31·5	3·5	11·0	7·0	8·3
8	115·3	1·5	46·5	35·0	4·0	11·0	9·0	7·0
9	112·1	0·7	41·5	40·0	4·0	11·0	13·0	8·0

* C 18 : 3 linolenic acid, C 18 : 2 linoleic acid, C 18 : 1 oleic acid, C 18 : 0 stearic acid, C 16 : 0 palmitic acid as determined by gas liquid chromatography.
† Original oil.

Fatty Acid Composition and Amount of Natural Linoleic Acid in Soya-bean Oil Hydrogenated with a Copper Catalyst

Iodine value	Composition (wt. %) from gas liquid chromatography C 18 : 3	C 18 : 2	C 18 : 1	C 18 : 0	C 16 : 0	Content of natural linoleic acid (wt. %)	% Natural linoleic acid of gas liquid chromatography linoleic acid
133·5*	7·5	51·0	25·5	3·5	11·5	50·7	100
111·3	Trace	44·5	39·5	4·0	11·0	34·4	77
112·8	Trace	46·0	38·5	4·0	11·0	39·9	87
114·2	0·8	46·5	37·0	4·0	10·5	38·6	83
119·2	2·0	50·0	32·5	3·5	11·5	36·4	73

* Original oil.

Table (Cont.)

Compositional Changes in Oils by Hydrogenation

C. Popescu et al. (341) - Soybean oil

Analytical Results of Hydrogenated Soybean Oil

Experiment no.	% Fatty ester GLC				Iodine value calc.	Alkali isomerization			
	St[a]	M[a]	D[a]	T[a]		% Lo[a]	% Le[a]	% Conj. dienes	% *trans*
Original soybean oil for Exp. 1 and 2	4	25	53	10	136	50.2	8.3	...	.....
Original soybean oil for Exps. 3 to 7	4	25	52	9	136	45.5	7.5	...	.....
1	4	48	38	1	108	28.1	0.0	0.6	18.9
2	4	61	24	0	94	.....	.....	.....	29.6
3	5	63	23	0	94	10.0	0.0	0.0	32.3
4	5	48	36	3	110	23.1	2.2	0.0	21.7
5	5	72	14	0	83	5.6	0.0	.....	31.6
6	5	66	20	.....	91	11.1	0.2	0.0	27.1
	16	73	2	0	68	.....	.....	.....	42.6
7	4	51	36	0	106	28.0	0.0	0.0	19.5

[a] St, stearate; M, monoenoate; D, dienoate; T, trienoate; Lo, linoleate; Le, linolenate.

D. Lambertsen et al. (250) - Fish oil

Relative Peak Areas From GLC of Diacetates From Monoenoic Acids in Hydrogenated Fish Oil Cleaved by Reductive Ozonolysis[a]

Chain length of monoenoic acid	Geometric isomer	Chain length of dialcohol									
		7	8	9	10	11	12	13	14	15	16
16	*cis*	15	60	100	80	52	27	16	10		
	trans	10	56	100	90	54	38	21	12		
18	*cis*	18	60	100	94	80	55	36	25		
	trans	12	67	100	98	88	73	45	--		
20	*cis*	14	37	61	78	100	71	42	25	13	8
	trans	8	18	46	73	100	73	47	29	20	13
22	*cis*		20	49	77	100	67	41	20	13	9
	trans		12	30	68	100	76	43	24	16	12

[a] Maximal peak area, 100.

The chemical aim of hydrogenation is to saturate selectively double bonds on polyene chains but not on monoene. Achieving this result is difficult; two other effects of hydrogenation are migration of double bonds and cis-trans isomerization (Hannewijk 167). These effects have been studied in monoene FA prepared from fish oils by Ackman et al. (013) and by Lambertsen et al. (250).

Tsuchiya and Akiyama (402) heated hardened soybean oil at 270-280°C for one to two hours with glycerol and reported a "marked degree" of re-esterification.

Hydrogenation gives rise to volatile by-products. Silveira et al. (370) hydrogenated a soybean oil of peroxide value 11.2 meq/kg with Ni catalyst 0.125% at 180°C, and fractionated an ether solution of the volatiles by gas chromatography (GC); fractions were further identified by infra-red and mass spectra. Twenty-one of 41 GC peaks were collected and 10 were identified (Table 5, A). The authors concluded that most of the volatile by-products were hydrocarbons but could only guess at their sources in the fresh oil.

Kawada et al. (228) hydrogenated a soybean oil of peroxide value 10.5 meq/kg at 120°C and identified 37 of 45 GC peaks from a CCl_4 solution of the volatiles (Table 5, B). Four of five unsaturated hydrocarbons were trans isomers. Peroxide value was little changed by hydrogenation. The authors concluded that refinement and deodorization of the oil immediately before hydrogenation could reduce the volatiles by 30-fold (confirmed by Hannewijk, 167), and pointed out that most commercially hydrogenated oils had peroxide values of only 0.5-2.0 meq/kg.

Table 5

Volatile By-Products of Hydrogenation of Oils

A. Soybean oil (Silveira *et al.* 370)

Gas Chromatographic Fractions Identified

Fraction number	Identified as
1	Acetone (tentative)
2	n-octane
3	n-nonane
5	n-hexanal
6	n-decane
10	n-hexanol
12	3-nonanone (by mass spectrum)
13	n-heptanol
15	n-decanal
18	n-decanol
20	n-heptadecane (by mass spectrum)

B. Soybean oil (Kawada *et al.* 228)

Compounds Identified as Volatile By-Products of Catalytic Hydrogenation

Peak No. in gas chromatograms	Size of peak	Identified as
1. Saturated hydrocarbons		
3-A	Small	n-Hexane
7-A	Medium	n-Octane
13-A	Medium	n-Nonane
19-A	Medium	n-Decane
24-B	Small	n-Undecane
29-A	Small	N-Dodecane
40-A	Medium	n-Tetradecane
42-A	Small	n-Hexadecane
44-A	Medium	n-Heptadecane

Table 5 (Cont.)

Peak No. in gas chromatograms	Size of peak	Identified as
2. Unsaturated Hydrocarbons		
8-A	Small	*trans*-Octene
10-A	Small	*cis*-2-Octene
14-A	Small	*trans*-Nonene
20-A	Small	*trans*-Decene
31-C	Small	*trans*-Dodecene
3. Saturated alcohols		
12-A	Small	n-Propanol
18-A	Small	n-Butanol
23-A	Small	n-Pentanol
28-A	Large	n-Hexanol
33-A	Large	n-Heptanol
36-A	Medium	n-Octanol
39-A	Medium	n-Nonanol
41-A	Large	n-Decanol
4. Esters		
6-A	Medium	Ethyl acetate
5. Carbonyl compounds		
11-A	Small	n-Butanal
17-A	Small	n-Hexanal
34-A	Small	n-Nonanal
38-A	Small	n-Decanal
22-A	Medium	2-Heptanone
27-A	Small	2-Octanone
32-A	Small	2-Nonanone
15-A	Small	3-Hexanone
26-A	Medium	3-Octanone
31-B	Medium	3-Nonanone
25-A	Small	4-Octanone
30-C	Small	4-Nonanone
6. Lactones		
37-A	Small	γ-Hexalactone
45-A	Small	γ-Nonalactone

Numerals indicate the number of gas chromatographic peaks with Ucon Polar as stationary phase (same as the numbers in Fig. 1).

Letters indicate the number of gas chromatographic peak when re-chromatographed with SE-30 as stationary phase.

In short, the composition of fresh soybean oil varies. Hydrogenation is never complete; the degree differs from maker to maker; and the results vary. The composition of partly hydrogenated soybean oil is extremely variable and has never been fully determined.

III. Structural Formula

It follows from the preceding section that no meaningful structural formula can be given for soybean oil.

IV. Molecular Weight

Because soybean oil is a mixture, no molecular weight can be stated. Data for some FA components of fresh soybean oil are given in Table 1.

V. Specifications

No mention of hydrogenated soybean oil was found in the Food Chemicals Codex, 2nd Edition, 1972 (088); the National Formulary, 13th Edition, 1970 (026); the U.S. Pharmacopoiea, 18th Edition, 1960 (405); or Synthetic Organic Chemicals, U.S. Production and Sales (U.S. Tariff Commission) (408). No mention of soybean oil in any form was found in these compendia.

International specifications for "edible soya bean oil" have been recommended by the Codex Alimentarius Commission (CAC) of the Joint FAO/WHO* Food Standards Programme (085). Some of these recommendations are abstracted in Table 6. Item 6.1.2 in Table 6 covers hydrogenated soybean oil and implies that it may be different (it is a product, whereas unhydrogenated soybean oil may be classed

* Food and Agricultural Organization and World Health Organization of the United Nations Organization.

as produce). The hydrogenated oil appears to be covered by the FAO/WHO Recommended General Standard for Edible Fats and Oils Not Covered by Individual Codex Standards (083); some of the recommendations are abstracted in Table 7.

In short, no binding specifications that unequivocally describe hydrogenated soybean oil (or its synonyms; see Nomenclature) have been found. Even the CAC recommended standards are not yet in force; they await ratification and adoption by the Member Nations of FAO/WHO.

VI. Description

Although the chemistry of hydrogenated oils is somewhat uncertain, their physical handling characteristics are more predictable; oils are partly hydrogenated in order to elaborate products of improved stability and suitable plasticity, which varies according to the procedures used.

Hannewijk (167) has reviewed the principles of hydrogenation and has emphasized the following points: Crude oils with over 0.1% of FFA must be bleached and neutralized before being hydrogenated, but other impurities including bound aldehydes (which give bad flavor) are removed by normal refining. The hydrogen must be free from S and CO. High temperatures improve the selective hydrogenation of higher PUFA; however, if the oil becomes hotter than about 200°C aromatic FA bound to glycerol tend to be formed. The catalyst usually is solid, of known pore size, and contains Ni. Its contamination with S enhances cis-trans isomerization resulting in a fat that is firmer

Table 6

Codex Alimentarius Recommended International Standard
for Edible Soya Bean Oil (085). Some Abstracted Specifications

2.1.1. Relative density (20°C/water at 20°C)	0.919 - 0.925
2.1.2. Refractive index (n_D40°C)	1.466 - 1.470
2.1.3. Saponification value (mg KOH/g oil)	189 - 195
2.1.4. Iodine value (Wijs)	120 - 143
2.1.5. Unsaponifiable matter	not over 15 g/kg
2.2.3. Acid value	not over 0.6 mg KOH/g oil
2.2.4. Peroxide value	not over 10 meq peroxide oxygen/kg oil
3.3 Antioxidants and synergists:	
3.3.1. Gallates, i/c*	100 mg/kg
3.3.2-3.7 BHT, BHA, i/c, with/without gallates	200 mg/kg
3.3.4-5. Ascorbyl palmitate/stearate i/c	200 mg/kg
3.3.7. Dilauryl thiodipropionate	200 mg/kg
3.3.6. Tocopherols	unlimited
3.4.3-5. Isopropyl citrate mix, monoglyceride citrate, phosphoric acid, i/c	100 mg/kg
3.5 Dimethyl silicon, SiO_2, i/c	10 mg/kg
3.6 Oxystearin	1.25 g/kg
4.1 Matter volatile at 105°C	0.2% m/m
4.2 Insoluble impurities	0.05% m/m
4.3 Soap	0.005% m/m
4.4 Iron	1.5 mg/kg
4.5-4.7. Copper, Lead, Arsenic - each	0.1 mg/kg

6.1.2. Where soya bean oil has been subjected to any process of esterification or to processing which alters its fatty acid composition or its consistency the name soya bean oil or any synonym shall not be used unless qualified to indicate the nature of the process.

6.2.1. A complete list of ingredients shall be declared on the label in descending order of proportion.

* i/c = individually or in combination

Table 7

Codex Alimentarius Recommended International General Standard for Edible Fats and Oils (085): Some Extracted Specifications

---

3.3 Odor and Taste: .... free from foreign and rancid odor and taste

3.4 Acid Value: Non-virgin fats and oils - not more than 0.6 mg KOH/g fat or oil

3.5 Peroxide Value: Not more than 10 meq of peroxide oxygen/kg fat or oil

4.3.2-11 Emulsifiers: maximum 20 g/kg inclusive, of a list of 10 classes of substances, individually or in combination

4.4-7 Antioxidants, Antioxidant Synergists, Anti-foaming Agents, and Crystallization Inhibitors: A long list of individual maxima

5. Contaminants, Maximal levels:

5.1	Matter volatile at 105°C -	0.2% m/m
5.2	Insoluble impurities -	0.05% m/m
5.3	Soap -	0.005% m/m
5.4	Iron (Fe), non-virgin oil -	1.5 mg/kg
5.5	Copper (Cu), non-virgin oil -	0.1 mg/kg
5.6	Lead (Pb) -	0.1 mg/kg
5.7	Arsenic (As) -	0.1 mg/kg

7. Labeling provisions include "a complete list of ingredients" (7.2.1); "net contents" (7.3); "name and address" of supplier (7.4).

---

at room temperatures; S contamination accumulates, however, and has to be watched.

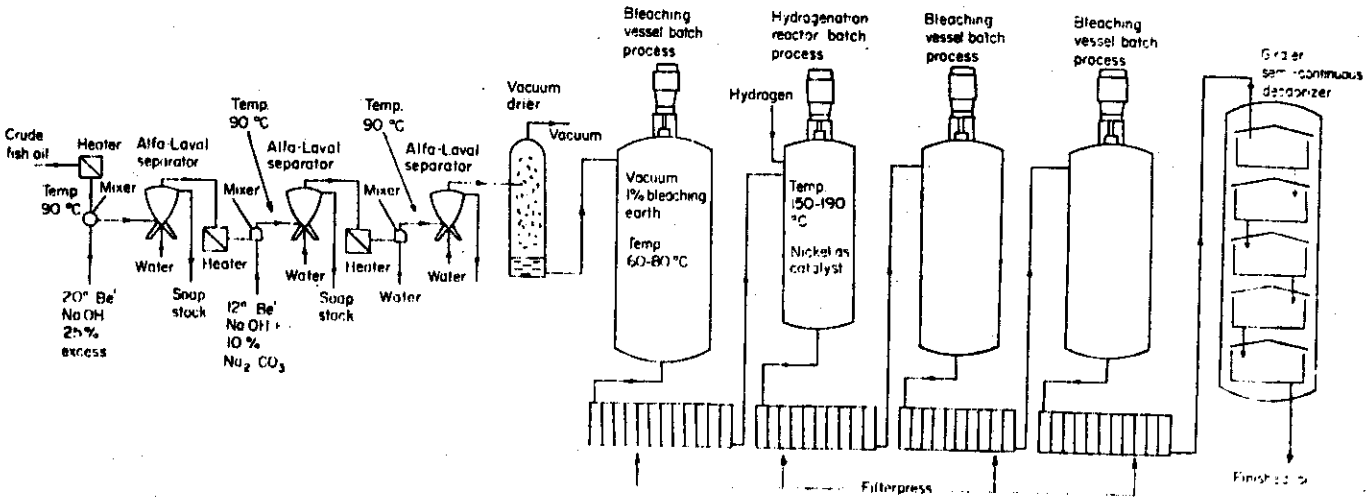
Chang (081) has reviewed the processes in detail, with flow charts (Figure 1) and diagrams of types of apparatus commonly used, including alternatives. He comments that while Cu-containing catalysts hydrogenate more selectively than Ni catalysts (they leave out the monoene FA), they cost more and the products are more prone to oxidize. He notes that oils are finally deodorized at 190-230°C in the United States, but at 170-190°C in Europe to avoid possibly harmful thermal decomposition and polymerization.

Koritala (246) investigated 26 solvents for selective hydrogenation at various temperatures and pressures, and concluded in favor of high polarity, although the chemical mechanisms were unclear. The flavor of soybean oils hydrogenated at lower temperatures was more stable if the process was more selective.

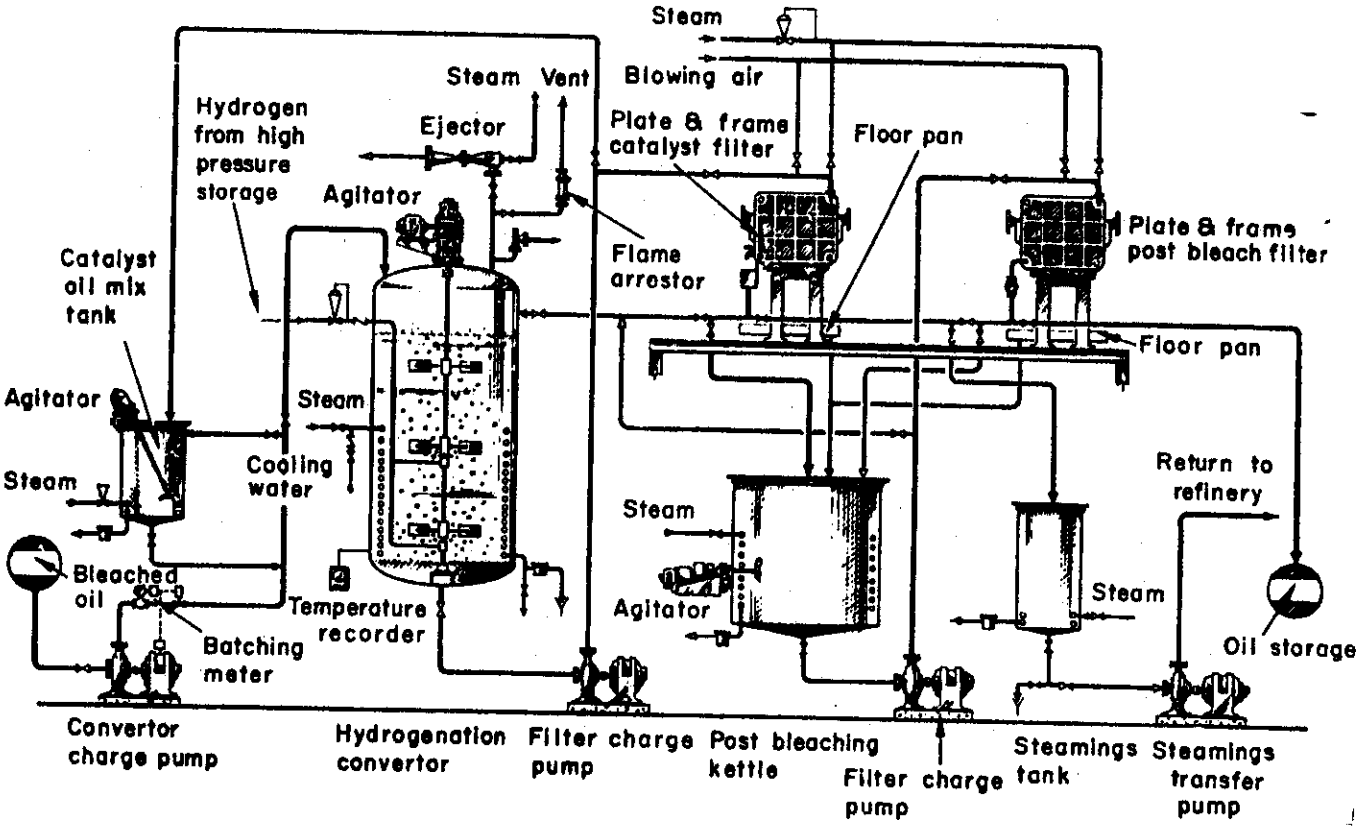
In a continued search for these qualities, Koritala (245) and his coworkers (089) re-examined the merits of Cu-Cr and Cu-oxide catalysts in comparison with Ni. Though the search was inconclusive they found that bad odor and flavor, as judged by a taste panel, was related to levels of linolenate and isomers of linoleate in the finished oils.

Popescu et al. (341) reported production of highly monoene (oleate) soybean oil using a Cu-Cr-Ni mixture as catalyst, and that Cu residues were "readily removed" by refining or treatment with citric or phosphoric acids. Beal et al. (041) compared many methods of removing Cu residues and concluded in favor of treatment with cation-exchange resin followed by deodorization with 0.01% citric acid.

Fig. 1. General Procedures of Hydrogenation From Chang (081)



A. Flow Sheet of Fish-Oil Processing



B. Lay-out of a Hydrogenation Plant (From Bailey's Industrial Oil and Fat Products by Daniel Swern.)

Table 8

Some Physical Characteristics of Soybean Fatty Acids*

FASEB Serial No.	Iodine Number**	Molecular Weight	Melting Point °C	Boiling Point °C (at mm Hg)	Specific Gravity (at °C)	Refractive Index*** (at °C)	Soluble in****
(12)	0	200.3	44.2	225(100)	0.8690(50)	1.4261(60)	acet,alc,eth,pet.eth.
(14)	0	228.4	53.9	250(100)	0.8622(54)	1.4273(70)	acet,alc,eth,pet.eth.
(16)	0	256.4	63.1	268(100)	0.8487(70)	1.4309(70)	acet,h.alc,eth,pet.eth.
(18)	0	284.5	69.6	213(5)	0.8390(80)	1.4337(70)	acet,h.alc,eth,pet.eth.
(20)	0	312.5	76.5-77.0	201(1)	0.8240(100)	1.4250(100)	bz,chl,eth,pet.eth.
(87)	112.13	226.35	18-18.5	185(13)	0.9024(20)	1.4559(20)	bz,pet.eth.
(95)	99.77	254.40	-0.5 to +0.5	140-141(5)	-	-	-
(117)	89.86	282.45	9.8-10.4; 26.5-27.5	196(1.5)	-	-	-
(159)	181.01	280.44	-5	229-230(16)	0.9031(20)	1.4711(20)	acet,alc,eth,pet.eth.
(180)	273.51	278.40	-11.3 to -11	125(0.05)	0.9164(20)	1.4800(20)	acet,eth,me.alc,pet.eth.
(191)	273.51	278.40	-11.3 to -11	125(0.05)	0.9164(20)	1.4678(50)	acet,alc,eth,pet.eth.

* Identified in Table 1, compare FASEB serial numbers. Not hydrogenated.
** Grams of I absorbed by 100 g of acid. Sp. Gr. referred to water at 4°C.
*** At the D-line of Na (589nm).
**** acet = acetone; alc = alcohol (ethyl unless otherwise specified); h = hot; me = methyl; eth = diethyl ether; pet = petroleum; bz = benzene; chl = chloroform.
Gaps mean no data reported in Table 2 ( ).

Miyake et al. (305) have attributed these and other problems of hydrogenation to incompatible kinetics of the various reactions.

In short, the catalyst that will hydrogenate perfectly and leave no toxic traces has not yet been found. This is evidenced by the continual patenting of claims for minor improvements of method (046,299,314,371) and see General Bibliography).

Hydrogenated oils and fats are mixtures of lipids with very different mp and expansion spectra, which causes them to be described as relatively "steep" or "flat." To some extent these variations are carried over from the starting material, shown in Table 8.

Partly hydrogenated fats and oils are treated with weak alkali to remove traces of FFA and Ni-catalyst and are then bleached and deodorized (see Fig. 1). The question of stability will be considered later (see Biochemical Aspects - Breakdown).

Vitamin losses during refinement, hydrogenation, and finishing have been studied by Loury (254). He found about 20% reduction of the tocopherol levels present in crude soybean oil. Although the antioxidant properties of tocopherols are important for keeping quality (see Breakdown), Loury did not consider the losses to be significant.

Hydrogenation results in some aversive "hardening flavors." Hannewijk (167) states that they vary with the degree to which the PUFA are saturated and with the mp spectrum, being greater at lower mp. He attributes these results to the presence of free ketones and especially free aldehydes, and notes that levels above taste thresholds can develop within hours in daylight and about 2 months

in the dark.

Meijboom (294) tried to relate the odors and tastes of some pure saturated and unsaturated aldehydes to their molecular structures. He found, as have others, that the technical problems are enormous. Today these problems remain unsolved (077). Nevertheless, Meijboom and his coworkers (230) appear to have identified the principal carrier of hardening flavor in hydrogenated linseed and soybean oils as 6-trans-nonenal, which was detected by some subjects at a dilution of 0.3 ppb.

In short, partly hydrogenated soybean oil has no precise physical description. Subjective, empirical judgments, based on reports by sensory evaluation panels, tend to govern the commercial acceptability of the diverse forms of such oil.

VII. Analytical Methods

Probably no complete analysis of any sample of partly hydrogenated soybean oil has ever been made.

No records were found of officially specified methods. Recommended methods for estimating compliance with the CAC Recommended International Standards await ratification. These are listed in the Standards for Edible Soybean Oil (085) and Edible Fats and Oils (083) (see Specifications); they also appear in the Standard for Margarine (084) to the extent that this product contains a high ratio of hydrogenated soybean oil (see Consumer Exposure).

O'Connor et al. (322) reported a method for detecting soybean oil when it is mixed with cottonseed and peanut oils, which do not contain linolenic acid. The approximate number of triene conjugations

is determined by spectrophotometry at 268 nanometers; this, however, is not quantitative for soybean oil (see Empirical Formula) and is useless after part-hydrogenation of the oils.

Ueno (409) found a relationship between iodine number and thiocyanogen value determined by "the usual method, employing the pure acetic acid," which, he claimed, reflected the degree of hydrogenation of a fish oil.

Feuger and Bailey (131) described a physical estimate of hydrogenation, using a "micropenetrometer" with a sharp needle. They plotted temperature against "micropenetrations" of 0-25 mm, drew regular curves for iodine number sequences in partly hydrogenated peanut, cottonseed, and soybean oils, and claimed that the results indicated degrees of plasticity.

Malins and Mangold (266) and Mangold (272) reported that thin layer chromatography (TLC) could be used to analyze complex lipid mixtures, using equipment and techniques that are now standard. Mangold (272) claimed advantages over previously existing methods in simplicity, speed, efficiency, sensitivity, and capacity, and he recognized that the chief use for TLC in lipid analysis would be for preparative fractionation. His paper contains 235 literature references and is cited as authoritative in many recent reports included in this monograph.

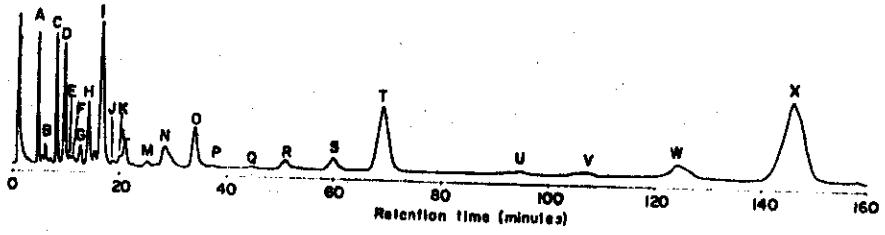
The state of the art in 1967 was reviewed by Malins and Wekell (267). Mangold and his coworkers (221) have continued to extend their TLC techniques, concentrating on adsorbents with special affinities for separating the more recondite fractions of natural

oils, including soybean oils.

The FA spectrum in natural oils, including partly hydrogenated soybean oil, is now generally determined by gas or gas-liquid chromatography (GLC) of TLC fractions. This work has been reported by many authors including Karmen et al. (218) and Kuemmel and Chapman (248). Principles, techniques, analytical standards, and some results, are summarized by Houle (197), some of whose illustrations are reproduced in Figure 2.

Fig. 2. Examples of Gas-Liquid Chromatographic Analysis of Natural Oils for Fatty Acid Spectrum

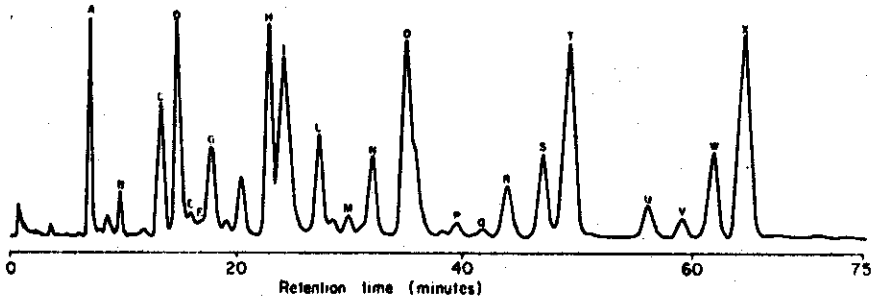
From Houle (197)



A. Isothermal GLC Analysis of the Fatty Acid Methyl Esters of Menhaden Oil

Instrument: Aerograph 6000, hydrogen flame ionization detector. Column: Ten percent diethyleneglycol succinate on 100/120 mesh Chromosorb W. Ten feet times one-eighth inch outside diameter pyrex glass column. Conditions of analysis: Temperature, 178°C; Nitrogen carrier gas flow rate, 30 ml/min.; Hydrogen flow rate, 24 ml/min.; and Air flow rate, 400 ml/min. Identification of individual peaks on the chromatogram. (Fatty acid chain length; number of double bonds). A, 14:0; B, 15:0; C, 16:0; D, 16:1; E, 17:0; F, 16:2; G, 17:1; H, 18:0; I, 18:1; J, 19:0; K, 17:3 or 18:2; L, 18:2; M, 20:0; N, 18:3; O, 20:1; P, 20:2; Q, 22:0; R, 22:1 or 20:4, S, 20:4; T, 20:5; U, 24:1 and 22:4; V, 22:4; W, 22:5; and X, 22:6.

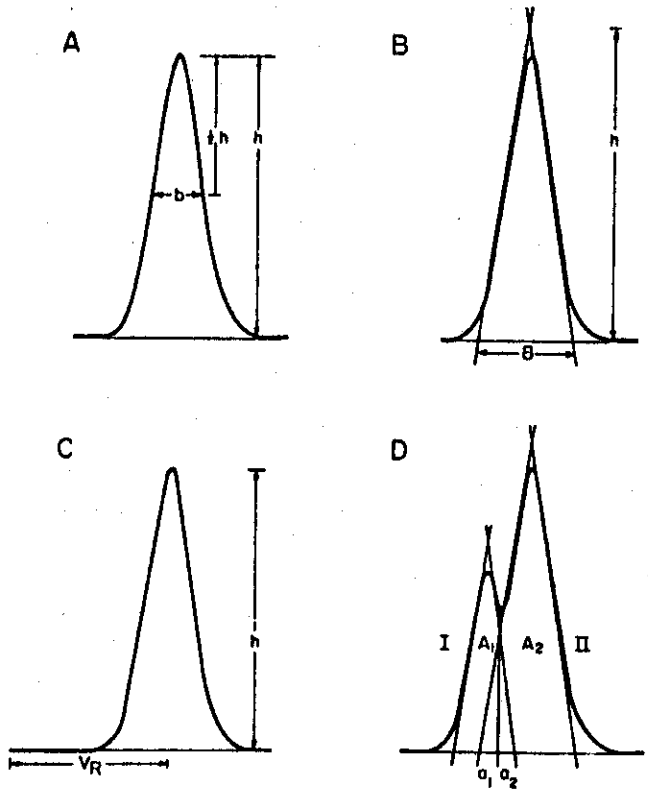
Fig. 2 (cont.)



B. Programmed Temperature GLC Analysis of the Fatty Acid Methyl Esters of Menhaden Oil

Instrument: Barber-Coleman Model 5000, dual hydrogen flame ionization detectors. Column: Six feet times one-quarter inch outside diameter, packed with five percent stabilized diethyleneglycol succinate on 80/90 mesh Anakrom ABS. Conditions of analysis: Column temperature at start of run, 130°C. Temperature program rate of 1°C/min. Nitrogen carrier gas flow rate of 60 ml/min.; Hydrogen flow rate of 39 ml/min.; Air flow rate of 400 ml/min. Identification of individual peaks on the chromatogram. (Fatty acid chain length; number of double bonds). A, 14:0; B, 15:0; C, 16:0; D, 16:1; E,F,G, identity uncertain; H, 18:0; I, 18:0; L, 18:2; M, 20:0; N, 18:3; O, 20:1; P,Q, identity uncertain; R, 22:1 or 20:4; S, 20:4; T, 20:5; U, 24:1 and 22:4; V, 22:4; W, 22:5; and X, 22:6.

Fig. 2 (cont.)



C. Common Methods of Measurement of Peak Areas

A, Peak height times base at one-half height. B, Triangulation; Peak height times one-half the base. C, Retention time times peak height. D, Measurement of incompletely resolved peaks by triangulation.

Attempts to measure "plasticity" using objective, modern technology have been reported. For example, Pohle and Gregory (337) described a stage in the development of standards for determination of solids in fats and shortenings by nuclear magnetic resonance, and concluded that confirmation of their results by others was required.

The phospholipid fraction of soybean oil is about one-tenth the amount of the triglyceride fraction and can be measured by nitric-perchloric determinations of lipid phosphorus (for which the laboratory should be equipped with shatter-proof glass). Zhukov and Vereshchagin (429) have proposed some modifications that would reduce sample volume and improve both accuracy and safety.

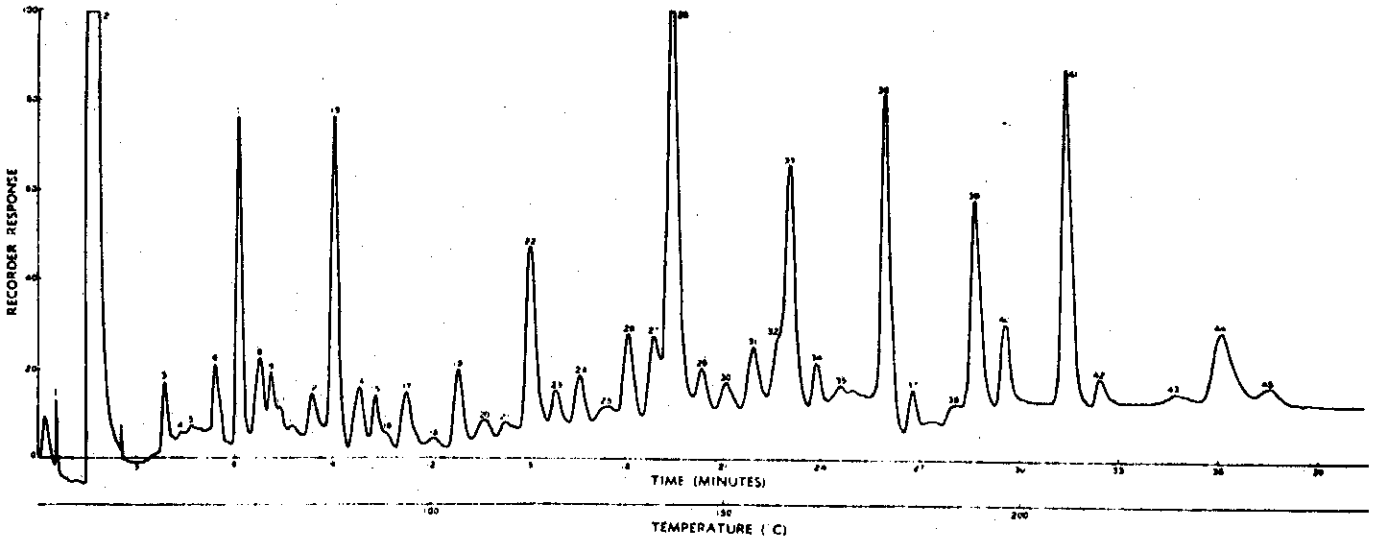
Ohlson (323) determined oxygen sorption in a number of oils including soybean oil under various conditions. He used a pH meter with an O electrode that measured a unit proportional to the partial pressure of oxygen. He found that hydrogenated oils absorbed oxygen more rapidly than raw oils.

Determination of oxidative rancidity using 2-thiobarbituric acid reagent was reported for fish oils by DeKonig and Silk (114). This is a standard method that determines the amount of malonaldehyde arising from oxidative decomposition of polyene PUFA. Results were found to be parallel to peroxide values.

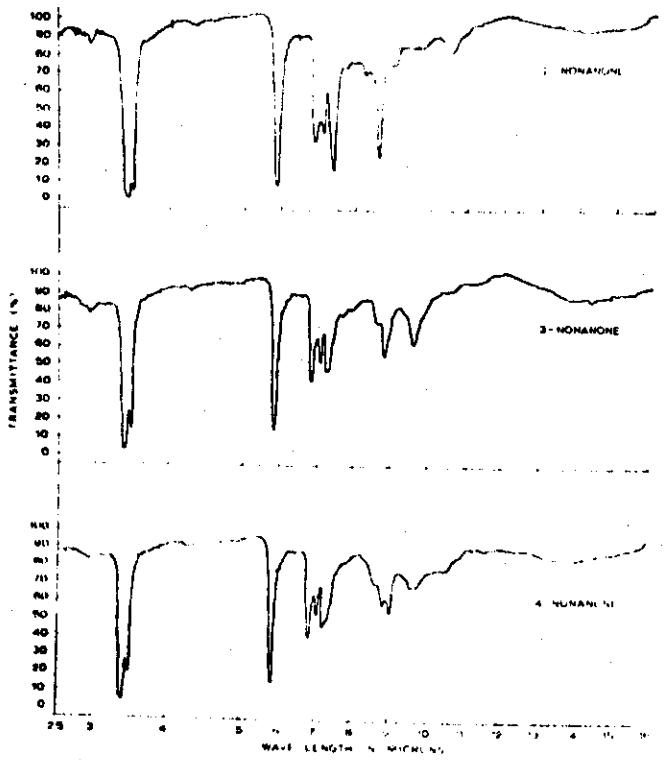
Chang and his coworkers (370,228) described the identification of volatile by-products of hydrogenation of soybean oil (see Table 5), principally by gas chromatography. Figure 3 illustrates some typical data.

Fig. 3. Gas Chromatogram of Volatiles of Hydrogenated Soybean Oil Studied Further by Infrared and Mass Spectra

From Kawada et al. (228)

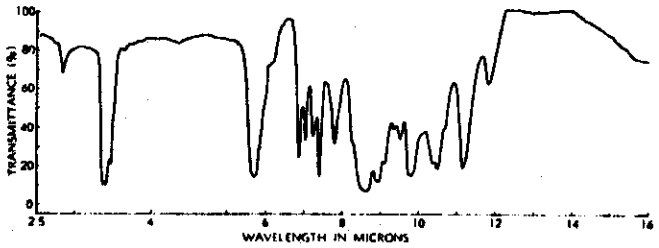


A. Gas chromatogram of the volatile by-products developed during hydrogenation of soybean oil

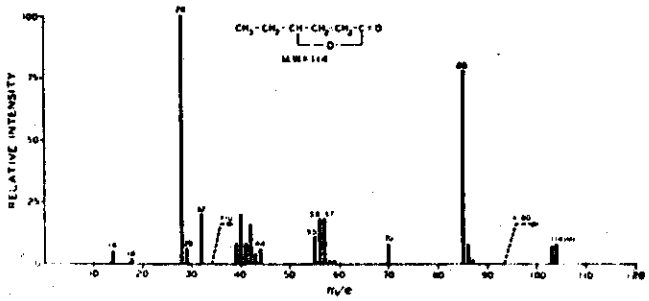


B. Infrared spectra of 2-nonanone, 3-nonanone, and 4-nonanone

Fig. 3 (cont.)



C. Infrared spectrum of the fraction 45-A identified as γ-hexalactone



D. Mass spectrum of the fraction 45-A identified as γ-hexalactone

Copper residues in edible oils were determined by Deck and Kaiser (109) colorimetrically in EDTA solutions reacted with a sensitive phenanthroline compound. They claimed determinations of 0.002-0.1 ppm.

Arsenic and bromine determinations in edible oils down to 0.01 ppm were claimed by Lunde (257) after samples were fractionated on silica gel columns and submitted to neutron activation analysis.

VIII. Occurrence and Levels Found in

A. Plants. In 1970, in the USA, 761,265,000 bushels of soybeans yielded 8,261,000,000 pounds of oil, which is approximately 11 pounds per bushel (Agricultural Statistics 404). Yields of course vary from year to year and place to place.

B. Animals. Not applicable.

C. Synthetics. Not applicable.

D. Natural Inorganic Sources. Not applicable.

BIOLOGICAL DATA

I. Acute Toxicity

No reports have been found on acute toxicity of soybean oil.

Hydrogenated soybean oil is commonly regarded as a major nutrient, and major nutrients are not commonly regarded as acutely toxic.

Nevertheless, it may be relevant that Matsuo studied acute toxicity in fish oils for many years, and isolated and purified a cyclic monomer that proved acutely toxic to rats and rabbits. He (286) concluded that this monomer is an endproduct of autoxidation and peroxidation of many edible oils. Confirmation has not been found in the literature for hydrogenated soybean oil.

Woods et al. (423) found a potentially lethal dermatitis when chicks were fed 20% of their diet as vegetable oil. To see if this effect was due to skin contamination with diet, the authors applied a number of oils to the skin of 2-week-old chicks; those receiving unhydrogenated soybean oil developed severe skin lesions, and two out of five died within five days. When hydrogenated "vegetable" oil was used, one of six died. All of the oils were judged equally toxic when applied in this way. When the authors found that most of the damage could be prevented by adding antibiotics to the oils, they concluded that secondary infections were responsible.

Hakansson (163) looked for changes in an artificial soybean oil emulsion intended for intravenous injection and found increasing FFA levels at 6-36 months of storage. The aged emulsions were injected into dogs, and cell damage was reported in a number of

internal organs, together with changes in serum lipid and protein values. No reports have been found of similar effects of FFA from hydrogenated soybean oils administered orally.

II. Short Term Studies

Reports directly or indirectly relevant to hydrogenated soybean oil deal with five sorts of effect: (a) direct toxicity of the oil, (b) nutritional imbalance, (c) EFA deficiency, (d) vitamin E or antioxidant deficiency, and (e) autoxidation and peroxidation effects. Most of these reports concern highly artificial experiments in animals.

a. Direct Toxicity

Thomasson et al. (399) fed groups of 24 male and 24 female rats a 60% (by kcal) fat diet for 12 weeks. Of the 60%, 54% was one of the fats shown in Table 9, and 6% was sunflower oil to provide EFA activity. The three soybean oils L5, L15, and L40 were hydrogenated in different ways.

Table 9

Dietary Fat Used in Short Term Toxicity Study
by Thomasson et al. (399)

Percentage FA composition of dietary fats

Type of experimental fat	Fatty acids				
		Monoene		Diene	
	Saturated	*cis*	*trans*	*cis-cis*	*trans*
Soya-bean oil (control)	15	24	0	55	0
Hydrogenated soya-bean oil (L_5)	21	12	54	6	4
Hydrogenated soya-bean oil (L_{15})	16	47	1	16	19
Hydrogenated soya-bean oil (L_{40})	15	22	14	41	7
Hydrogenated linseed oil	16	20	40	6	16
Hydrogenated olive oil	24	39	29	6	1
Butterfat	53	24	8	7	3

No significant differences from controls were found in food intake; body-weight gain; fecal fat; water intake; rectal temperature; kidney function as measured by urine s.g. and aspartate transaminase activity; liver function as measured by alkaline phosphatase and serum alanine transaminase activities; hemoglobin; hematocrit; hemolysis time in a thiourea medium; total and differential leucocyte counts; coagulation; platelet adhesiveness; or (at autopsy) weights and histological appearances of heart, liver, kidneys, adrenals, spleens, or testes. All of these observations appeared normal. Body fat compositions, in terms of saturated FA and of monoenoic, polyenoic, and trans acids, reflected those of the respective dietary fats.

b. Nutritional Imbalance

In a review of the nutritional properties of oils, Stansby (383) contrasted fish and vegetable oils to make the point that EFA should be defined more broadly and PUFA more precisely than many people do. He considered growth support and cholesterol depressant activities to outweigh the curing of dermal symptoms as criteria of EFA. Among PUFA he contrasted the properties of dienes (such as linoleate) that predominate in vegetable oils with those of trienes and higher polyenes that predominate in fish oils. He emphasized that oxidation effects were "all only potential" -- that is, that they reflected deterioration and would not necessarily follow ingestion of oil that was normally fit for human consumption.

Njaa et al. (320) fed young rats a low protein, low choline diet for four weeks. Diet calories were doubled by adding soybean oil hydrogenated to mp 40.5°C, hydrogenated marine fat, hydrogenated

rapeseed oil, natural herring oil, or lard. Herring oil produced some fatty livers. These excluded, the "hydrogenated" groups developed larger livers than the "natural" groups; for cause, the authors ruled out choline deficiency and suggested low linoleate intakes. The "hydrogenated" groups gained less weight, and the authors identified the probable cause as artificial polymerization (during hydrogenation) of C_{20} and C_{22} FA, because the group receiving soybean oil was least affected. Additions of α-tocopherol produced no effect.

Paluszak (333) fed a total of 80 rats one or the other of six diets, which included in some cases a fully (maximally), hydrogenated rapeseed oil. The principal effect of this oil was to eliminate all adipose tissue. Toxic residues in the oil were exonerated, and the author concluded that deficiencies of EFA and biotin were responsible.

c. EFA Deficiency

Aaes-Jørgensen (007) defined substances that would qualify as EFA as follows: "The criteria for a polyenoic acid belonging to the group of essential fatty acids are: a long chain with cis-double bonds in divinyl methane arrangement, and the first double bond in position 6 counted from the methyl end of the molecule (ω-6-position)." Examples given were linoleic acid, ω-linolenic acid, and arachidonic acid, considered as members of the "linoleic acid family." The word "family" reflects convertibility by metabolism in the body. EFA actions included cure of dermal symptoms, restoration of growth, prevention of damage to kidneys and reproductive tissues, and prevention of accumulation of eicosatrienoic acids normally present at

low levels. Unlike Stansby, Aaes-Jørgensen (007) excluded cholesterol-depression as not being "linked exclusively" to EFA. He pointed out that FA of the linolenic (ω-3) family promoted growth but did not cure dermal symptoms, and argued that the oleic-palmitoleic ratio might provide a chemical indicator of EFA deficiency; these could be biosynthesized (by man) while linoleic and linolenic acids could not. Study of these inferences was urged by the author for two practical reasons: the nutritional contribution of PUFA to phospholipids, and their readiness to autoxidize (see below).

Aaes-Jørgensen and Hølmer (008) fed different diets (Table 10) to five groups each of 30 weanling male rats and found that part-hydrogenated soybean oil or natural arachis oil more than doubled the growth rate compared with hydrogenated herring or arachis oils or fat-free diet (Figure 4).

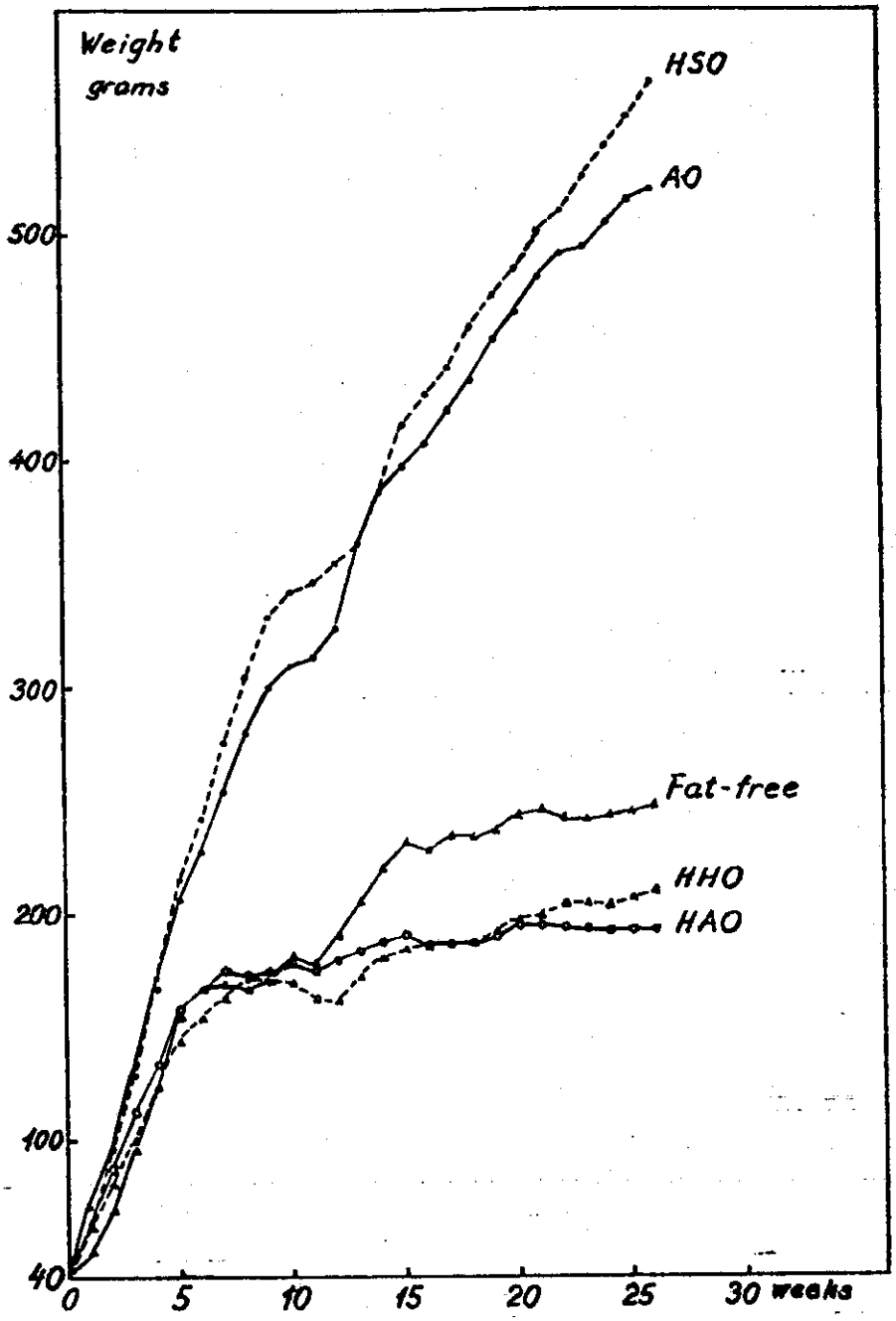
Table 10

Dietary Fats Used in Short Term EFA Study by Aaes-Jørgensen and Hølmer (189)

Fatty acids, per cent of oil	Partially hydrogenated arachis oil (HAO)	Partially hydrogenated soybean oil (HSO)	Arachis oil (AO)	Partially hydrogenated herring oil (HHO)
	Fatty Acids of Dietary Oils (Wt %)			
Saturated	29.3	19.8	19.1	41.9
Monoenoic	67.0[a]	41.4[b]	50.9[c]	44.8[d]
Polyenoic	3.3	39.0	29.9	13.2
$C_{18:2}$, ω6 Linoleic acid	0.8	31.8	28.8	0.6
$C_{18:3}$, ω3 Linolenic acid	—	3.4	1.1	—
Total trans acids (as Elaidic acid)	47	10.7	0	22.9

[a] $C_{16:1}$, 1%; $C_{18:1}$, 64.8%; $C_{20:1}$, 1.2%.
[b] $C_{16:1}$, 0.6%; $C_{18:1}$, 40.8%.
[c] $C_{16:1}$, 0.3%; $C_{18:1}$, 48.5%; $C_{20:1}$, 1.7%.
[d] $C_{16:1}$, 5.6%; $C_{18:1}$, 13.0%; $C_{20:1}$, 11.3%; $C_{22:1}$, 14.1%.

Fig. 4. Growth Rates of Rats in The Short Term EFA Study by Aaes-Jørgensen and Hølmer (189).



Average growth rate of male rats fed on a diet with 28% partially hydrogenated soybean oil (HSO), 28% partially hydrogenated herring oil (HHO), 28% partially hydrogenated arachis oil (HAO), 28% arachis oil (AO), or a fat-free diet (Fat-free).

The hydrogenated herring oil degenerated the testicles in 5 weeks, the hydrogenated arachis oil in 15, the fat-free diet in 26, and the hydrogenated soybean oil caused no degeneration in 26 weeks. The oil still contained 32% linoleic acid, and a total of 11% of *trans* acids calculated as elaidic. However, the authors pointed out that the ultimate chemical basis of these different effects remained speculative.

d. Vitamin E or Antioxidant Deficiency

Blaxter *et al.* (055) fed 42 neonatal bull calves a ration designed to produce muscular dystrophy; 27 also received either α-tocopheryl acetate, ascorbic acid, biotin, ethyl gallate, or methylene blue. Only α-tocopheryl acetate when given by mouth, and methylene blue, were found to be protective. The authors concluded that antioxidant activity could not be the basis of this protection, and they emphasized that the role of vitamin E was unknown at that time.

Ershoff (126) fed immature rats a basal low-fat diet containing 71% sucrose and 24% casein supplemented (or not) with one or more of many oils including three levels of soybean oil (2, 5, and 10%). Fish oils resulted in diarrhea and growth retardation; these effects were counteracted by adding 10% soybean, cottonseed, sesame, corn, or wheat germ oils, but not by addition of methyl linoleate, butterfat, lard, or olive, coconut, or hydrogenated cottonseed oils. α-Tocopherol, but not α-tocopheryl acetate, gave some protection, as also did DPPD (N,N'-diphenyl-p-phenylenediamine), Santoquin, sesamol, Torula yeast 10%, desiccated liver NF, alfalfa meal 20%, casein, fishmeal, and a mixture of crystalline amino acids, or DL-methionine 0.6%. The author

concluded that this protection in these animals was due to antioxidant activity.

Dam (099), using chicks, recognized that two separate actions were involved, and suggested that vitamin E was stabilized in the body by other antioxidants, which at the same time duplicated the antioxidant activity of the vitamin.

What should not be forgotten is that basal diets of the type given by Ershoff to young rats cause an immense induction of enzymes of the oxidative and anerobic pathways of glycolysis (360), and that this result greatly influences the metabolism of particular FA (420-- see Biochemical Effects).

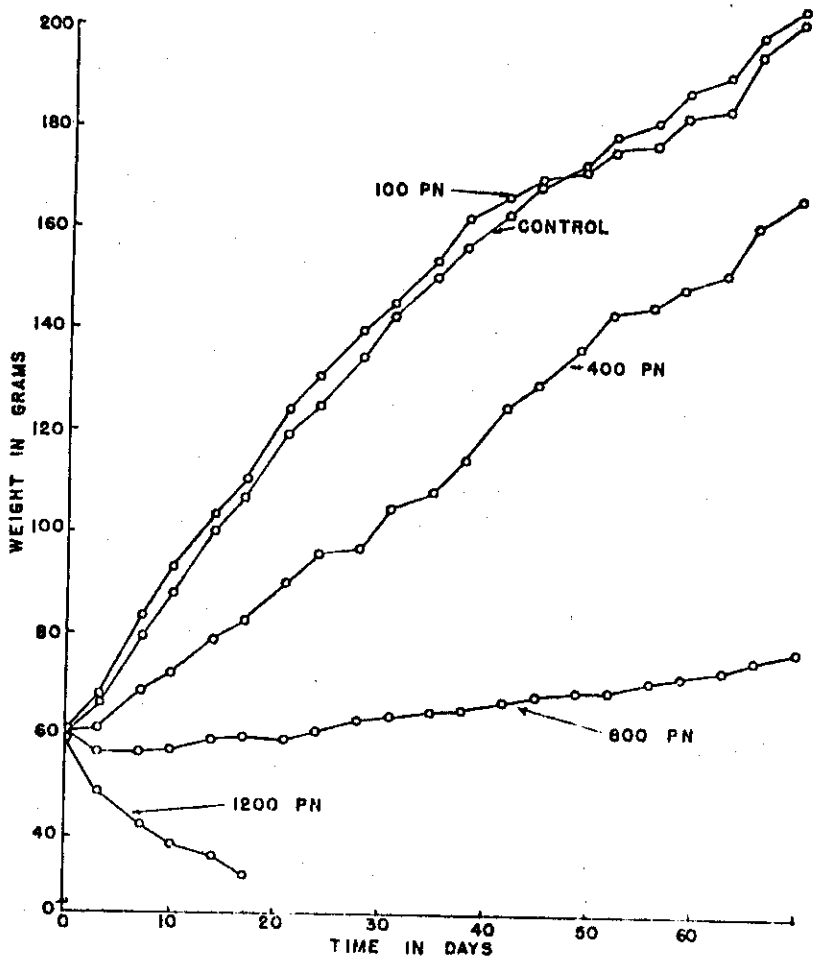
Harris and Embree (169) studied the relationship between intakes of PUFA and requirements for vitamin E in man. They calculated the average intakes of PUFA in g per head of the population of the United States for the year 1960, and the average intakes of Vitamin E expressed as mg of d-α-tocopherol. The ratio, mg of vitamin E to g of PUFA, was found to be 0.6, and the authors inferred from published data that this ratio was probably marginal for protection of man against vitamin E deficiency. However, Scott (367) gives reasons to suspect that the value of this ratio may have been partly due to selenium deficiency. Very recently, the National Academy of Sciences has issued a denial of suggestions that vitamin E deficiency may be widespread in the United States at the present time (317).

e. Autoxidation and Peroxidation Effects

Andrews et al. (029) oxidized some raw soybean oil under controlled conditions to peroxide values of 13, 927, 1156, and 3185,

and found these fractions to contain conjugated dienes at 0, 1190, 780, and 1602 meq/kg respectively (showing further uncontrolled decomposition). They then adjusted the fractions to peroxide values of 100, 400, 800, and 1200, and fed them to four groups of 10 rats each, but not to a fifth group, for 10 weeks as 15% of a diet containing 61% sucrose and 18% casein. The effects on growth of the females are shown in Figure 5.

Fig. 5. Growth of Rats Versus Peroxide Value of Fats From Andrews et al. (029)



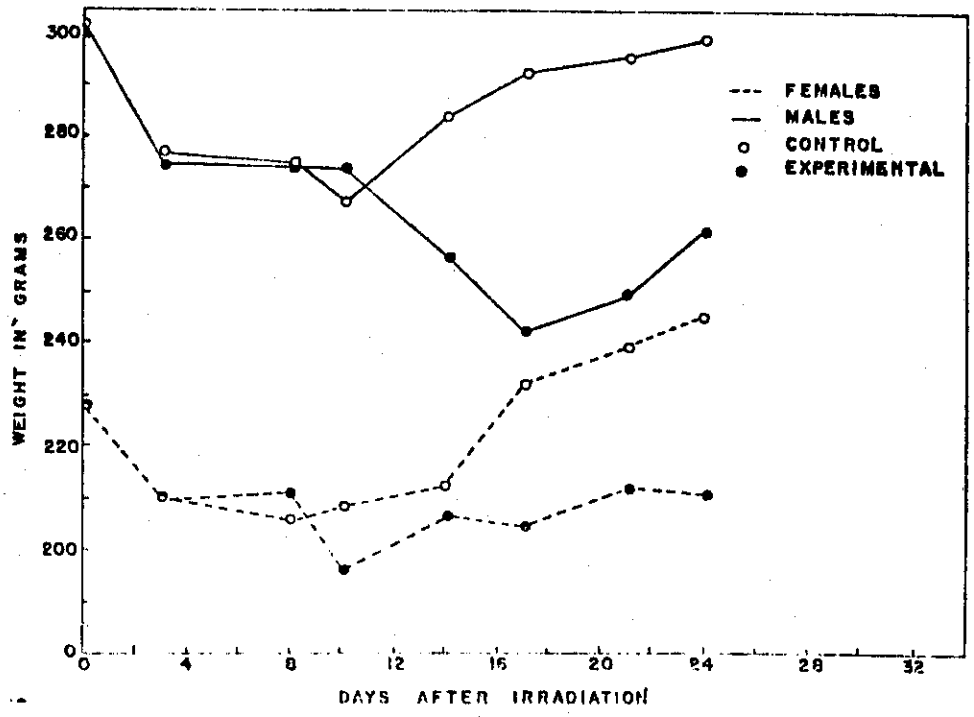
Growth of female rats receiving various levels of oxidized fat

The lowest group all died within three weeks; the authors state that the graph for the males was similar. Although the diet containing oil of peroxide value 100 had no effect on growth in this experiment, it severely diminished growth during recovery from whole-body irradiation (Fig. 6A). These and other studies showed that the growth effect was related quantitatively to the peroxide value. At autopsy it seemed probable that the intestine was the site of toxicity; thoracic duct cannulations also had indicated that peroxides were destroyed in the gut, though their reduced products were absorbed. However, the toxic event was not revealed. In any event, a peroxide value of 13 did not seem to be toxic to growth (Fig. 6B).

Fig. 6. Effects of Moderate Peroxide Values on Growth of Rats Under Special Circumstances

From Andrews et al. (029)

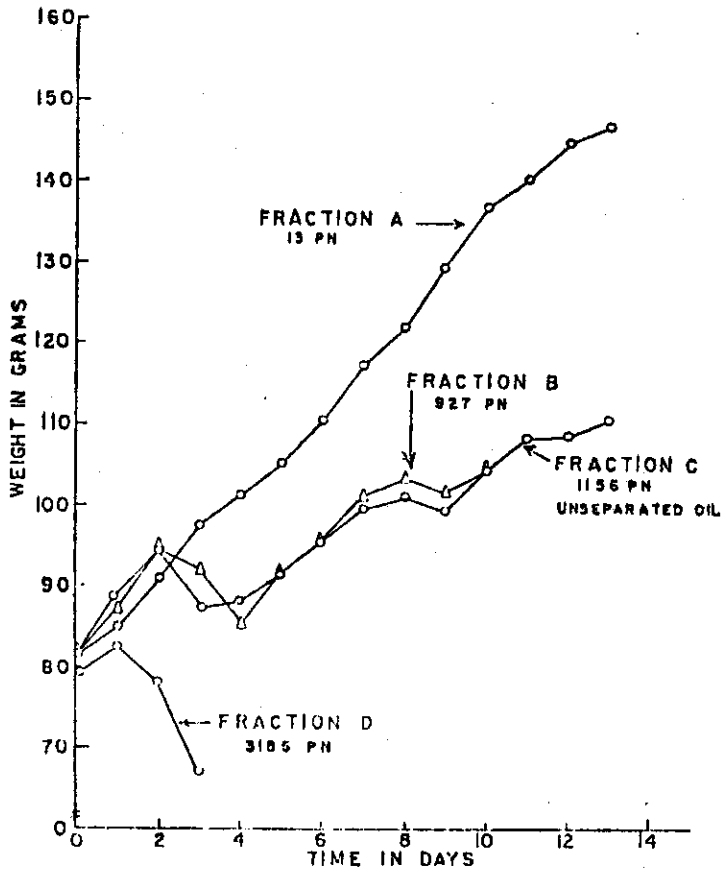
A. Soybean oil of peroxide value 100 fed as 15 percent of a diet during recovery from whole-body irradiation



Effect of diet on recovery from whole body irradiation

Fig. 6 (cont.)

B. Effect of fractions of oxidized soybean oil of various peroxide values



Growth of rats receiving various fractions of oxidized soybean oil

Roubal and Tappel (357) studied the in vitro effects of peroxidizing lipids, typified by ethyl arachidonate, on the integrity of proteins and amino aicds. Measurable denaturation was found in six proteins. Five proteins were analyzed for damage to their amino acids, and seventeen of those were reported damaged. Causation of the damage was attributed to generation of transient free radicals. In addition, cysteine was part-converted to cystine with liberation of H_2S. The authors concluded that such damage "appears to be about

one-tenth as effective as radiation damage."

The pathway by which peroxidic free radicals were generated during autoxidation of linoleic acid was reported by Dam (099). The possibility that the cyclic monomer, isolated by Matsuo (286), may arise as an endproduct of peroxidation in hydrogenated soybean oil was implied by the author but has not been demonstrated in fact.

III. Long Term Studies

No reports on long term studies of chronic toxicity of hydrogenated or partly hydrogenated soybean oil have been found in the literature.

Nevertheless, there appears to be a theoretical possibility that epoxides might arise either during metabolism of peroxides in the intestine or by action of drug-metabolizing enzyme systems on soybean oil hydrocarbons (see Breakdown); there is a further possibility that such hydrocarbons might be carcinogenic. This could apply, of course, to virtually all edible oils if overheated during frying. Grover (158) has reviewed the mechanisms. Apparently epoxides that form at the K regions (regions of high electron density associated with isolated phenanthrenoid double bonds) or other regions of cyclic hydrocarbons are electrophilic. When these epoxides react with nucleic acids in vitro or in cultured cells, alkylation may occur; or alternatively, an epoxide may be intercalated into DNA or may delete a DNA base, and each case could result in a frameshift mutation. On reinjection into rodents, resultant morphologically abnormal cell colonies reportedly have been found to

be malignant.

None of these effects have been reported for partly hydrogenated soybean oil *in vitro* or *in vivo*. However, the rate of growth of carcinosarcoma in rats was reported by Haven (174) to be faster when the dietary fat was coconut oil of iodine number 157 than when it was cod liver oil of iodine number 9; the variation was attributed to the difference in saturation of the respective PUFA.

The current debate about the possible carcinogenicity of selenium may be indirectly relevant to hydrogenated soybean oil. As reviewed by Scott (367), Se has long been known to have a sparing effect upon vitamin E both in chicks and in second-generation rats. Se reportedly participates in the glutathione peroxidase reaction in rat erythrocytes. Reportedly, there is a "very high incidence of selenium deficiency in the eastern part of the United States." This deficiency is due to low Se content of animal feeds, including soybean meal, as well as to its low biological availability (65% average for soybean meal), resulting in losses among poultry and severe Se deficiencies in other livestock. A request to the Food and Drug Administration (FDA) from the American Food Manufacturers Association (AFMA) to permit supplementation of feeds with Se to a level of 0.25-0.35 ppm (dated 3.9.1970) has been delayed by uncertainty as to the status of Se under the Delaney Amendment. According to Scott, Se is an essential nutrient in the range 0.1-0.3 ppm in the total diet but produces chronic toxicity in the range 2-10 ppm. In the lower range, according to Scott, it has been shown to inhibit cancers, while "a carcinogenic effect of high

Table 11

FDA Tolerances for Pesticides in Oil Seeds in 1968, And Amounts Added to Cottonseed Oil Before Its Refinement in Order to Determine Their Persistence [Adapted from Gooding (147)]

Pesticide	FDA Tolerance, ppm	Amount Added
Aldrin	0.25	1.0
Benzenehexachloride(BHC)	5.0	15.0
Chlordane	0.3	1.0
DDT	7.0	21.0
Dieldrin	0.1	1.0
Heptachlor	0.0	1.0
Heptachlor Epoxide-99.4%	0.0	1.0
Kelthane	0.1	1.0
Lindane	10.0	30.0
Methoxychlor	14.0	42.0
Sesone	6.0	18.0
Strobane	5.0	15.0
TDE or DDD	7.0	21.0
Toxaphene	7.0	21.0

residues in edible oils (as contrasted with seeds) and concluded that none were needed.

Stout (389) monitored food fish caught in the Northwest Pacific for levels of DDT and related pesticides, and found up to 0.4 ppm which she attributed to agricultural run-off.

Smith et al. (378) conducted a controlled study to see if Gooding's results could be repeated. They used, in all, five samples each of cottonseed and soybean oils. Levels of fortification were 1.0 ppm for endrin, DDE, aldrin, dieldrin, heptachlor, and heptachlor epoxide, and 21.0 ppm for DDT. Three laboratories participated, and methods were "essentially equivalent" to those prescribed by the FDA. For convenience the data are assembled in Table 12. Although these experiments were performed under pilot-plant rather than commercial conditions, the authors decided that the "preponderance of evidence" supported a conclusion that processed edible oils are free of chlorinated residues including endrin. They speculated that any residues surviving refinement would be volatilized and removed during hydrogenation, deodorization, or both.

Stout et al. (390) reported that all detectable amounts of p,p'-DDT could be removed from fish oils by refining and 90% could be removed by dehydrogenation; however, p,p'-DDE levels were substantially reduced but not eliminated. Reviewing their own and others' studies the authors concluded that oils, including vegetable oils, should be deodorized at 230°C or higher (pressure 6 mm Hg) to remove 95% of chlorinated pesticides, and that

Table 12

Removal of Chlorinated Pesticide Residues From Samples of Cottonseed and Soybean Oils During Refinement and Dehydrogenation

From Smith et al. (378)

A. Results Obtained in Processing the Vegetable Oils Under Pilot Plant Conditions[a]

Process	SBO-1	SBO-2	SBO-3	SBO-4	SBO-5	CSO-1	CSO-2	CSO-3	CSO-4	CSO-5
Refining										
Quantity of oil refined, lb.	222	226	210	222	295	225	212	221	203	295
Free fatty acids in oil, wt. %	0.71	0.72	1.17	0.30	0.30	2.70	2.75	2.60	2.20	0.49
Caustic used, lb.	12.6	19.2	20.4	16.9	22.5	21.6	20.8	21.0	17.9	23.2
Refined oil recovered, lb.	209	204	182	187	260	191	178	182	178	241
Refining loss, wt. %	5.9	9.7	13.3	15.8	11.9	15.1	16.0	18.4	12.3	18.8
Bleaching										
Quantity of oil bleached, lb.	206	201	179	184	255	188	175	179	175	236
Bleached oil recovered, lb.	197	200	176	175	245	187	168	176	162	225
Hydrogenation										
Quantity of oil hydrogenated, lb.		197		172						
Hydrogenated oil recovered, lb.		147		86						
Deodorization										
Quantity of oil deodorized, lb.	194	147	173	200[b]	200	184	165	173	159	200
Deodorized oil recovered, lb.	189	136	170	198	190	172	156	166	144	186
Condensate recovered, lb.	0	0.25	0.25	4.0	4.0	3.75	0.5	0.25	0.25	0.25

[a] SBO = Soybean oil.
CSO = Cottonseed oil.
[b] Composed of 86 lb. hydrogenated SBO-4 and 114 lb. deodorized SBO-2.

B. Level of Endrin Detected in the Various Crude Vegetable Oil Lots

Oil sample	Location produced	Level endrin found (ppm)[a]			
		Lab 1	Lab 2	Lab 3	Average[b]
SBO-1	Area suspected of contamination	0.61	0.78	0.48	0.62
SBO-2	Area suspected of contamination	0.77	0.51	0.14	0.48
SBO-3	Area suspected of contamination	0.41	0.43	0.36	0.40
SBO-4	Area suspected of contamination	0.35	0.24	0.07	0.22
SBO-5	Area not suspected of contamination	BDL	BDL	0.03	0.01
CSO-1	Area suspected of contamination	BDL	0.03	BDL	0.01
CSO-2	Area suspected of contamination	BDL	0.19	BDL	0.06
CSO-3	Area suspected of contamination	BDL	BDL	0.03	0.01
CSO-4	Area suspected of contamination	I	BDL	BDL	BDL
CSO-5	Area not suspected of contamination	BDL	0.05	BDL	0.02

[a] SBO = Soybean oil.
CSO = Cottonseed oil.
BDL = Below detectable limits of analysis.
I = Interference in sample analysis.
[b] Calculated by taking average of values reported by the three laboratories.

C. Effect of Processing on Endrin Residue Levels in Four Soybean Oils Initially Suspected of Pesticide Contamination[a]

Oil sample	Crude oil	Refined oil	Bleached oil	Deodorized oil
		ppm		
SBO-1	0.62	0.59	0.51	BDL[b]
SBO-2	0.48	0.30	0.35	BDL
SBO-3	0.40	0.64	0.48	BDL
SBO-4	0.22	0.30	0.20	BDL
Mean	0.43	0.46	0.41	BDL

[a] Individual crude, bleached and deodorized oil values represent mean analyses of the three laboratories. Two analyses compose the refined oil values.
[b] BDL = Below detectable limits of analysis.

D. Pesticide Residues Found in Fortified Cottonseed Oils at Various Stages of Processing[a]

	Refined oil	Bleached oil	Deodorized oil
	ppm		
Endrin	0.42	0.65	[b]
DDT	11.1	12.5	[c]
DDE	0.92	0.83	BDL[d]
Aldrin	0.55	0.65	BDL
Dieldrin	0.72	0.64	BDL
Heptachlor	0.58	0.69	BDL
Heptachlor epoxide	0.77	0.86	BDL

[a] Average pesticide value of two oils with three independent laboratory analytical values per oil.
[b] Values (CSO-1, 0.07; CSO-2, 0.08) were reported by one laboratory and the other two laboratories could not confirm the presence of a detectable level of residue.
[c] A value of 0.06 ppm was reported for CSO-2 by one laboratory and not confirmed by other laboratory analyses.
[d] BDL = Below detectable limits of analysis.

E. Average Endrin Content in Various Oil Fractions Obtained in Processing the Four Soybean Oils[a]

	Total endrin content
	mg
Crude oil	43.1
Soapstock oil loss	4.8
Refined oil	40.9
Bleached oil	36.5
Deodorized oil	BDL[b]

[a] Values are calculated from mean endrin analyses and oil fraction weights of the four soybean oils.
[b] BDL = Below detectable limits of analysis.

refining, bleaching, and hydrogenation were relatively ineffective. They pointed to risks of thermal degradation and emphasized that deodorization should be prolonged when temperatures were restricted to the more usual 190-200°C.

Thus in the literature consulted during preparation of this monograph, there was disagreement about the efficacy of the usual processes of refinement, hydrogenation, and deodorization for removing all, or even substantially all, traces of chlorinated pesticide residues from edible vegetable oils, including partly hydrogenated soybean oil. The data show that some residues can persist, and it is a fact that no official tolerance levels have been set.

Less work has been reported on detection and removal of polychlorinated biphenyls (PCB), which can accidentally contaminate edible oils. Beezhold and Stout (043) have described a gas chromatographic method of detecting PCB in fishery products, but they report problems with analytical standards that are still being studied. No reports were found on elimination of PCB.

BIOCHEMICAL ASPECTS

I. Breakdown

Perhaps the first stage of breakdown is the formation of volatile by-products during hydrogenation. These give rise to the well-known "hardening flavor" and are largely removed during deodorization.

Kawada et al. (228) analyzed by gas chromatography a soybean oil, commercially refined and bleached, with iodine number 131 and peroxide value 10.5 meq/kg (contrasted with the usual 0.5-2.0 meq/kg). The results have already been given (Table 5 and Figure 3). The authors identified gamma-hexalactone (Fig. 3, parts C & D) by the logic illustrated in Figure 7. They stressed that volatile derivates of hydroperoxides generated by hydrogenation differ in quality and quantity from those resulting from autoxidation.

Lea (252) studied the oxidation of lard in contact with an aqueous phase and found it to be more rapid at lower pH. He found that Cu accelerated oxidation when diluted to 0.01 ppm, and that Fe was about 5% as active. Antioxidants varied in their inhibitory effects, and Lea concluded that they did not function by antagonizing the pro-oxidant property of Cu; he thought that Cu might function by destroying natural antioxidants.

No detailed studies of autoxidizing hydrogenated soybean oil were found; some data on other oils are given to show the sorts of experiments that may be needed.

Wyatt and Day (424) analyzed autoxidizing salmon oil quantitatively for volatile carbonyl compounds (Table 13). No such list was found for autoxidizing hydrogenated soybean oil.

Figure 7

Identification of Gamma-Hexalactone By Mass Spectrum and Its Derivation From Hydroperoxides of Hydrogenation

From Kawada et al. (228)

A. Interpretation of the mass spectrum of the gas chromatographic fraction identified as γ-hexalactone

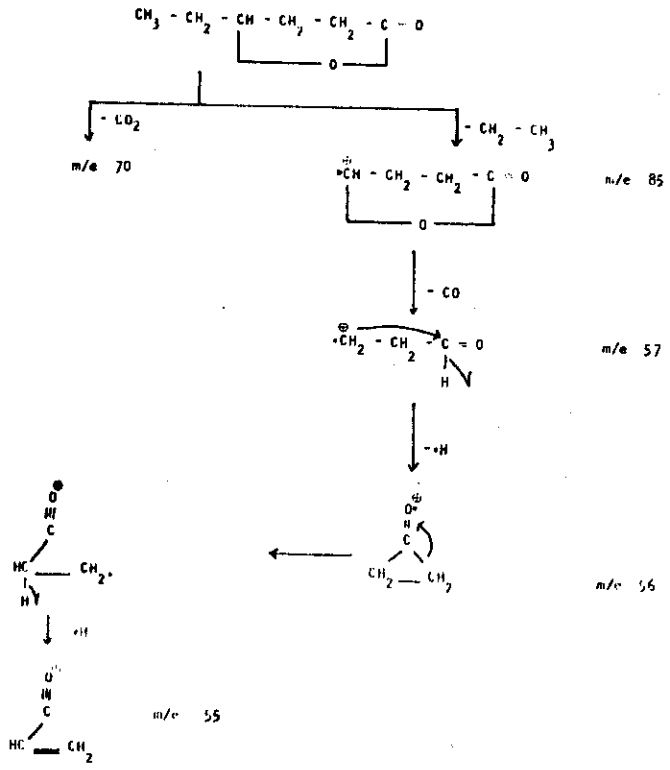
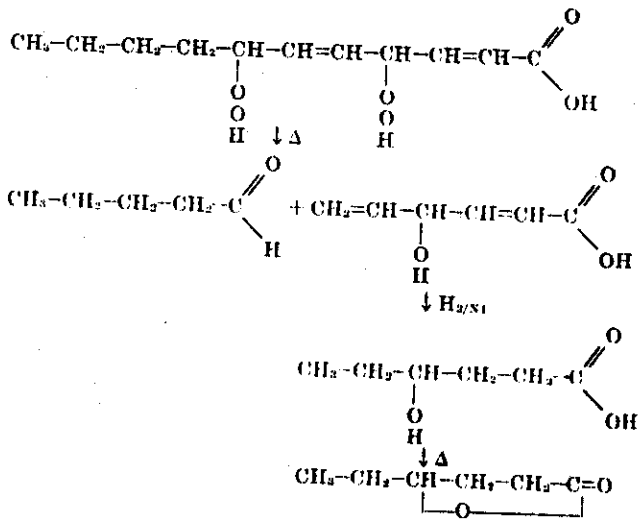


Figure 7 (cont.)

B. The lactones could only be formed through hydroxy acids. A mechanism for the formation of γ-hexalactone from the dihydroperoxide of a free fatty acid which may originate from linoleate is postulated as following:



C. A second mechanism involves the secondary autoxidation of 3-*cis*-hexenoic acid is also possible. This acid may be produced by the autoxidation of linolenate as follows:

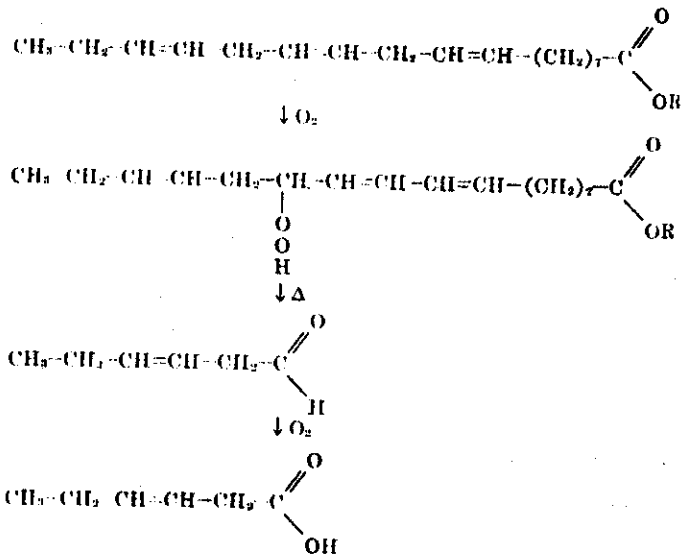
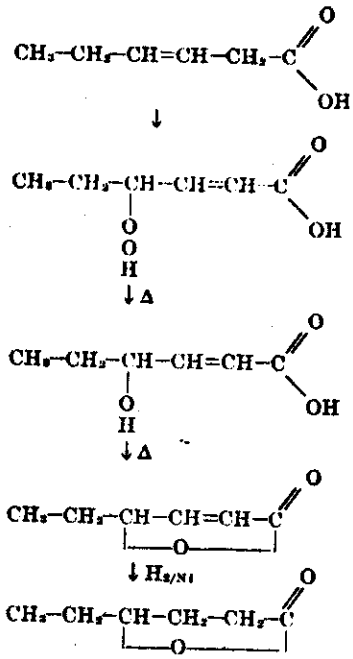


Fig. 7 (cont.)

D. This acid may form a hydroperoxide which is relatively nonvolatile and may remain in the oil during the deodorization previous to hydrogenation.



Chipault (082) found that the volatile carbonyls of oxidized fish oils included formaldehyde, acetaldehyde, propionaldehyde, butyraldehyde, valeraldehyde, hexaldehyde, acetone, butanone, pentanone, alpha-beta-unsaturated monocarbonyls, glyoxal, other low-mw alpha-keto aldehydes and diketones, and 2,4-dinitrophenyl-hydrazones not further identified. The basic fractions of the volatiles contained small amounts of amines, and the acidic fractions, only acetic and propionic acids.

Olcott (326) has summarized the biochemistry of autoxidation and antioxidants in oils, as shown in Figure 8. Steps (1)-(3) are "characteristic of free radical chain reactions" as to speed and

Table 13

Carbonyl Compounds in Autoxidizing Salmon Oil

From Wyatt and Day (424)

A. Gross changes in salmon oil during oxidation

	Sample no.				
	1	2	3	4	5
Days' storage	0	16	31	66	163
TBA no.	8.35	350	1102	2024	1472
Peroxide value	4.0	62.6	171	224	358
Total carbonyls[a]	9.5	52.6	110.8	312.3	569.8
Volatile monocarbonyls[a]	0.096	0.176	0.562	1.463	2.057
Girard-isolable[a] monocarbonyls	4.456	3.820	98.670	77.888	19.209
Volatile dicarbonyls[a]	0.039	0.047	0.289	0.308	0.890
Girard-isolable[a] dicarbonyls	0.194	1.114	3.309	5.972	8.250

[a]mM/kg of oil

Table 13 (cont.)

B. Volatile monocarbonyl compounds from autoxidizing salmon oil (mM/kg).

	Sample no.				
	1	2	3	4	5
Alkanals					
n-Dodecanal	.0029	.0017	...	...	.0126
n-Undecanal	.0023	.0022	.0058	.0709	.0194
n-Decanal	.0022	.0018	.0102	.0705	.0675
n-Nonanal	...	.0019	.0058	.1292	.0606
n-Octanal	.0015	.0016	.0087	.1212	.0720
n-Heptanal	.0020	.0023	.0109	.0758	.0755
n-Hexanal	.0024	.0043	.0310	.2234	.2549
n-Pentanal	.0025	.0097	.0358	.1794	.0269
n-Butanal	...	.0036	.0375	.0698	.0274
n-Propanal	.0079	.0421	.1287	...	.1875
n-Ethanal	.0168	.0062	.0621	...	.1600
n-Methanal	.0111	.0720	.1335	...	.0514
Total	.0516	.1494	.4700	.9400	1.0517
Alk-2-enals					
Dodec-2-enal	.0008	.0006	.0010	.0031	.0407
Undec-2-enal	.0011	.0006	.0008	.0041	.0101
Dec-2-enal	.0016	.0015	.0018	.0139	.0275
Non-2-enal	.0010	.0010	.0025	.0291	.0407
Oct-2-enal	.0012	.0013	.0019	.0272	.0473
Hept-2-enal	.0023	.0022	.0025	.0595	.0891
Hex-2-enal	.0024	.0030	.0205	.0724	.2463
Pent-2-enal	.0054	.0034	.0262	.0451	.2386
But-2-enal	...	...	.0146	...	...
Total	.0159	.0135	.0717	.2543	.7412
Alk-2,4-dienals					
Dec-2,4-dienal	.0022	.0010	.0008	.0198	.0080
Non-2,4-dienal	.0012	.0004	...	.0120	.0627
Oct-2,4-dienal	.0025	.0011	.0023	.0225	.0458
Hept-2,4-dienal	.0227	.0102	.0143	.1704	.1005
Hex-2,4-dienal	...	.0009	.0029	.0441	.0471
Total	.0285	.0135	.0204	.2688	.2641

Table 13 (cont.)

C. Volatile dicarbonyl compounds from autoxidizing salmon oil (mM/kg).

Fraction	Sample no. 1	2	3	4	5
1	.0019	.0150	.0742	.0213	.2211
2	.0345	.0065	.0550	.1455	.1982
3	.0027	.0098	.0631	.0923	.0734
4	...	.0164	.0966	.0491	.3968

extent, and step (4) shows the formation of additional radicals during decomposition of the hydroperoxide. An antioxidant (AH) reacts with a free radical formed in the early stages to give an intermediate that is incapable of continuing the chain reaction. Naturally occurring antioxidants mainly are methyl derivatives of tocol, in which the side chain R_4 is either a hydrocarbon chain (C_{17}) or a triene group, as shown in the table at the bottom of Figure 8.

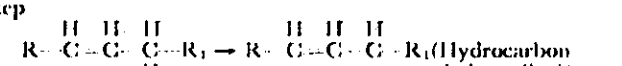
Figure 8

Typical Autoxidation and Action of Antioxidants

From Olcott (326)

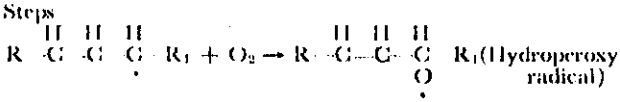
A. Oxidation

Initiation Step

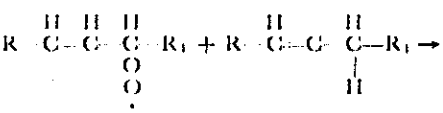


(1)

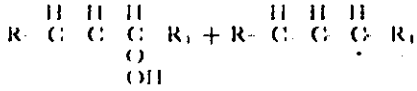
Propagation Steps



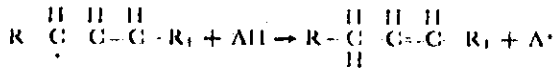
(2)



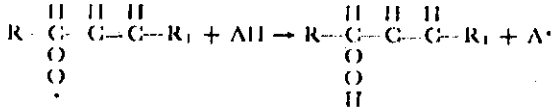
(3)



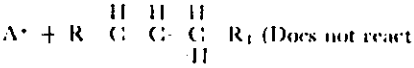
B. Antioxidant (AH) reactions



(5)



(6)

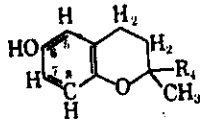


(7)

$$A\cdot + A\cdot \rightarrow AA \text{ (Terminates)} \qquad (8)$$

Figure 8 (cont.)

c. Tocol and some derivatives



Tocol

STRUCTURE AND RELATIVE ANTIOXIDANT ACTIVITY OF TOCOPHEROLS IN SQUALENE (50°)[1]

	Methyl Groups	Relative Antioxidant Activity
Tocols		
Alpha	5,7,8	1
Beta	5,8	5
Gamma	7,8	18
Delta	8	11
Tocotrienols		
Zeta	5,7,8	1
Epsilon	5,8	4
Eta	7,8	10

[1] R_4 chain of tocol is $-CH_2(CH_2-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-CH_2)_3H$. R_4 side chain of tocotrienol is $-CH_2(CH_2-CH=\underset{\displaystyle CH_3}{\underset{|}{C}}-CH_2)_3H$.

As already mentioned, the reversion of hardening flavor in soybean oils is probably due partly to hydrogenation and oxidation of aldehydes to give 6-trans-nonenal and related compounds (385). Hannewijk has concluded that if hydrogenated oils are prepared carefully, supplementary antioxidants are not needed; if not, they are of little avail.

Hamberg and Samuelsson (164) studied the positional and stereochemical specificities of oxygenation of unsaturated FA by soybean lipoxidase. The reaction was found to be almost entirely specific, and the oxygen function was introduced at position ω-6 in all FA that reacted, except that in one sample a small amount of substrate was oxygenated at position ω-10. The requirements for substrates in this reaction were elucidated, and it appeared that hydrogen removal was the initial step of the reaction.

II. Absorption - Distribution

McCay and Paul (291) confirmed, in guinea pigs, that utilization of different fats including soybean oil diminished as the melting point rose. Their criterion was the proportion excreted in the feces. This conclusion implies, of course, that absorption of hydrogenated soybean oils will decrease as the iodine number diminishes, and may be as little as 60%.

Thomasson (397), using rats, divided 18 natural oils into five classes according to their rates of absorption but found, nevertheless, that the gut distribution was relatively constant at about 73%, 22%, and 5% in stomach, small intestine, and colon

respectively. Soybean oil, in the second fastest absorbed class, was relatively more abundant than average in the small intestine (28-38%); this, however, would not necessarily apply also to hydrogenated soybean oil.

Hartwell (173) studied the digestion of various fats by a semi-purified pancreatic lipase *in vitro*. She found that butter was digested more rapidly than other fats except for coconut, palm kernel and castor oils, and that soybean and hardened arachis oils were in the slower group that included animal fats and vegetable oils.

These studies together suggest that the mechanisms of digestion and absorption of hydrogenated soybean oil are the same as those for other fats regarded as major nutrients.

It is well known that fatty acids first synthesized in plants can persist through the food chain. Beare (042) fed rats a purified diet contianing 20% w/w of corn oil, hydrogenated herring oil, or margarine, and measured the FA distribution in liver, carcass, and milk fats. She found that the distribution of palmitic, palmitoleic, stearic, oleic, linoleic, linolenic, eicosanoic, eicosadienoic, and erucic acids in milk fat reflected their pattern in the diet, generally more closely than did their carcass distribution. Tissue levels of arachidonic acid, not provided in the diet, were related to dietary linoleic acid levels. Changes of dietary fat were followed by corresponding changes in tissue distribution of long-chain FA. Beare observed that the rats required a long time to adapt to utilization of erucic acid.

Mohrhauer and Holman (309) fed rats supplements of purified FA

(ethyl linoleate, ethyl arachidonate, or ethyl linolenate) at 0.1-10% of the calories, and measured the FA composition of the liver lipids. Linoleate over 1% was increasingly stored and converted into FA of the linoleate family (20:4 and 22:4 acids). Arachidonate also was stored increasingly and converted to 22:5-ω-6. Linolenic acid was stored and converted to 20:5, 22:5-ω-3, and 22:6: also the level of 20:4 was decreased. There was, however, no conversion to linolenate family from linoleate or arachidonate. All three FA diminished the level of 20:3.

Aaes-Jørgensen (004) reviewed the distribution of marker FA through the tissues, radiating from the mesentery, but did not include a discussion of soybean oil.

Imaichi et al. (200) used gas-liquid chromatography to study the FA composition of 210 samples of human depot fat removed at surgery from abdominal or thoracic walls. Ten of these patients were known to be high consumers of fish oils, and their depot fat contained twice the average levels of highly unsaturated long-chain PUFA. The authors also noted some sex differences in the distribution of palmitoleate, myristoleate, and stearate.

Hølmer and Aaes-Jørgensen (189) fed rats one or another of four oils as sole dietary fat; these were arachis oil, or partly hydrogenated oils of arachis, soybean or herring, with distinctive FA patterns, and they were given as 28% w/w of the basal diet. The distribution of neutral lipids and phospholipids in the testes was measured after 5, 15 and 26 weeks and was found to be consistent with tissue degeneration reported separately by the same authors (008)--see Short Term Studies.

leate to arachidonate was progressively inhibited by increasing amounts of linolenate in the diet.

Menzel and Olcott (297) studied the positional distribution of FA in various animal lecithins in vitro, and concluded that linoleic and arachidonic acids are probably interchangeable with "non-essential" polyenoic acids with regard to some biochemical reactions in metabolism.

Holman (188) reviewed the interrelationships between FA in metabolism and found them extensive, but emphasized that ω-3 and ω-6 acids were not interconverted. He proposed a system for chain elongation during metabolism, shown in Figure 9, which reflects competitive inhibitions of the type described by Mohrhauer and Holman (310). Thus the metabolism of PUFA would depend on the contents of the FA pool in the body, as well as on the distribution of PUFA in the diet; a balanced diet would take all of this into account.

These findings were pursued in greater detail by Brenner and Peluffo (064) and by Mohrhauer et al. (311), with results that are important to knowledge of FA metabolism in general, rather than to partly hydrogenated soybean oil in particular.

The situation with maximally hydrogenated oils appears, however, to be different. Paluszak (333) hydrogenated a sample of rapeseed oil to mp 59°C and iodine number 5, eliminating linoleate, linolenate, and arachidonate. He fed this as a diet supplement to young rats, with and without added cholesterol and biotin (1% and 2 ppm respectively), for 11 weeks. Losses of weight and disappearance of depot fat were attributed to deficiencies of EFA activity and of biotin associated with the extreme hydrogenation.

Horst et al. (193,194) fed rats a diet with 50% w/w soybean oil partly or maximally hydrogenated (iodine numbers 130, 62, and 9). At iodine number 9, linoleic acid disappeared from adipose tissue and total body fat; depot fat also disappeared and did not return after the rats had been transferred to basal diet for 10 weeks. The oil had been hydrogenated at 200°C, and the authors looked for thermal and isomerization effects. But, "toxic effect was not found in our rats. They seemed to be well and had a normal and healthy appearance despite their progressive loss of body weight." The authors suspected a block in endogenous FA synthesis from C_2 intermediates of the Krebs cycle, suggesting that maximally hydrogenated fats might inhibit lipogenesis from carbohydrates, and that this ought to be studied.

It is well known that a major route of excretion of lipids is the sweat. However, most fats are utilized by the body as energy sources, or are stored when food intakes are persistently excessive.

IV. Effects on Enzymes and Other Biochemical Parameters

As Horst and his coworkers (193,194) had suspected, and as already noted in the foregoing discussion of Vitamin E or Antioxidant Deficiency (Short Term Studies), the nature of the basal diet can greatly influence the observed metabolism, especially the presence of simple and readily soluble carbohydrates.

Williams and Carroll (420) designed some complicated experiments with rats to elucidate metabolic interactions between dietary proteins, carbohydrates, and fats. For carbohydrates, they used glucose or fructose; for fats, regular or high-oleic vegetable oils; and

proteins were selected of different amino acid compositions. Some of the diets were categorized as "imbalanced". At the end of each experiment, the amounts and FA compositions of body lipid accumulations were determined. In general the FA compositions of body lipids were found to reflect those of the oils fed. All of the "imbalanced" diets altered the FA compositions of liver and adipose tissue lipids so that the proportion of 18:0 was diminished, those of 16:1 and 18:1 were increased, and the ratio of 18:2/20:4 was increased. Fructose accentuated both the increases and the decreases from normal.

Thus, metabolic studies in animals receiving "basal" diets of casein and sucrose in ratios such as 20:70 w/w, supplemented with relatively small amounts of different oils, are of limited value for determining the metabolism of the oils or the effects of the oils on other metabolic processes. Such studies can reveal only what happens in the presence of massive lipogenesis from carbohydrate. The FA compositions of the oils were reflected in the body lipids, and the decreases and increases were accentuated by fructose.

Sassoon et al. (360) demonstrated (as have others) the extent to which diets high in soluble carbohydrate can induce increases of glycolytic pathway enzymes. Also, they elucidated part of the mechanisms of induction. Dror et al. (117) have shown that this induction disturbs the pattern of protein utilization in rats, causing a 35% loss of efficiency judged by nitrogen balances. Reviewing the time course of metabolism in the presence of high-soluble-carbohydrate diets, Sassoon (359) has suggested that enzymatic adaptations to glycolysis, rather than to gluconeogenesis from lipids,

can overwhelm many physiological processes; this is especially so with sucrose diets because fructose tends to evade the normal glycolytic pathways and to be converted almost directly to glyceraldehyde-3-phosphate.

Thus, studies in animals receiving "basal" diets of casein: sucrose 20:70 w/w, or thereabouts, that are supplemented with relatively small amounts of oils (part-substituted in many cases) can reveal only what happens to or because of the oils in the presence of massive lipogenesis.

Egwim and Sgoutas (120) fed rats a basal diet of casein and sucrose, 16:74% w/w, and for some groups they partly replaced sucrose isocalorically with 10% corn oil, 20% corn oil, or 20% partly hydrogenated soybean oil. Each oil characteristically altered the activities of acetyl-CoA carboxylase and FA synthetase in both liver and adipose tissues. The mechanisms of these effects were not identified, and without taking into account the lipogenicity of the basal diet, the authors speculated that the effects might be related to EFA activity and trans-FA content of the oil supplements.

Andrews et al. (029) added fresh or air-oxidized soybean oil, not hydrogenated, to a basal casein-sucrose diet, 18:61% w/w, fed to rats, and found that the activity of intestinal xanthine oxidase was lower when the diet contained the oxidized soybean oil. The authors concluded that the enzyme was inhibited by the oxidized oil, but they did not test for the decrease except in the presence of the sucrose. However, they did find that both milk xanthine oxidase and the rat intestinal enzyme were inhibited in vitro by t-butyl hydroperoxide.

These findings, therefore, may be regarded as suggestive but incomplete.

Booth et al. (061) reported that when various vegetable oils were added to a control diet fed to female mice, the mean weight of the uterus increased by varying amounts; it was nearly doubled by refined soybean oil. They described this activity as "estrogen-like," and implied that estrogens were among the lipids in the oils; however, they supplied no analytical evidence.

Mecchi et al. (293) fed chickens and turkeys a basal diet in which the source of the fats was not stated, and found that supplementation with 0.1% tocopherol "increased the tocopherol content and stability (induction period) of carcass fat." They confirmed this by analyses after the carcasses had been stored for nine months at +10°F.

Van der Steur (412) reviewed the effects of refining and hydrogenation on the stability of additives including the fat-soluble vitamins. He noted that little of vitamin E was lost, but much of vitamins A and D is; he cautioned, however, against over-replacement.

Kishimoto et al. (238) analyzed slices of the left cerebral hemispheres of patients who died of multiple sclerosis and found subnormal axon densities and ganglioside concentrations in the plaques; they also observed a FA composition of the plaques that resembled that of grey matter rather than that of the surrounding white matter. The composition of the surrounding white matter resembled that of control white matter from autopsies on healthy subjects.

Bernsohn and Stephanides (049) developed a theory that multiple sclerosis partly reflected demyelination resulting from dietary deficiency of ω-3 PUFA during the period of brain maturation. They associated the geographical distribution of diets poor in ω-3 PUFA with that of multiple sclerosis, noting that the disease was rare where soybean consumption was high. Fresh soybean oil is, of course, an excellent source of ω-3 PUFA, but this may not be so with some hydrogenated oils (see earlier discussion, e.g. Table 10).

Finally, a number of reports associate soybean oils or FA found especially in soybean oils with alterations of cholesterol concentrations in various body tissues.

Dam et al. (105) fed hamsters butterfat or a dietetic margarine containing about 40% linoleate (source not stated). After 6-7 weeks the hamsters were dissected; those in the margarine group had fewer cholesterol gallstones than those in the butter group. Where the fats were fed as 10% of the diet, the difference was highly significant ($P<0.01$) and, where 3% of the diet, the difference was significant ($P<0.05$).

Grollman (157) reported that of a large number of refined oils only some decreased blood pressure in animals with experimental hypertension. These included four fish oils and tung oil, but not soybean or other vegetable and land animal oils and fats that were tried. The site of action was presumed to be the kidney, and the active fraction of the oil was partly isolated but not identified.

Horlick (191) gave healthy students a fat-depleted diet supple-

mented with corn oil or one of two hydrogenated soybean oils (iodine numbers 40 and 75). Addition of the corn oil did not decrease the serum cholesterol level below that from the basal diet, but both soybean oils did; however, they were poorly absorbed and produced steatorrhea.

Zemplenyi (428) found that soybean oil (not hydrogenated) had no effect on development or regression of aortic atheromata of rabbits, or on related enzyme activities such as alkaline phosphatase, compared with control animals.

Horst et al. (194) fed rats a basal diet without sugars but with 25% of starch; other groups received this with equal amounts (w/w) of soybean oil hydrogenated to iodine numbers 130, 62, or 9 together with 1% of cholesterol. Serum lipids were elevated with oils of I numbers 130 and 62, and serum and liver cholesterol were elevated with oil of I number 130. There was no linoleate in the total body fat or adipose tissue of rats fed oil of I number 9.

Erickson et al. (124) fed seven diets, one of which was supplemented with partly hydrogenated soybean oil, to a total of 42 healthy men and administered 742 mg per day (average) of cholesterol to some of them; this raised the plasma cholesterol levels by an average 24-27 mg per 100 ml. The plasma cholesterol response to the type of fat fed was unaffected by hydrogenation, with or without the cholesterol supplement; neither did the plasma cholesterol level differ according to the dietary ratio of PUFA to saturated fats. Phospholipid levels in the plasma were also higher when the diet contained cholesterol, and were highest in the group that

received cocobutter as fat.

It is well known, of course, that the cholesterol/phospholipid ratio in the plasma is considered by many to be more important than the cholesterol level alone.

A Research Committee of 16 scientists (351) undertook a "controlled" trial of soybean oil (not hydrogenated) on 393 male patients who had recovered from their first myocardial infarction at hospitals in the region of London, England. Of two groups, one was given a diet low in saturated fats and supplemented with 85 g of soybean oil per day; individuals in the other ate their normal diets. The trial went on for nearly seven years; the shortest individual duration was two years, and the median about four years. Over a period of six months the serum cholesterol level of the soybean oil group fell an average 22%, and of the "free" diet group, 6%. There was no significant difference between the groups in the myocardial relapse rate. Relapses were unrelated to cholesterol levels, and the relapse rate was unaffected by the PUFA content of the diet.

Publication of these results was followed by letters of disappointment from Sinclair (372) and Gilder (143).

Stansby (384) reviewed the cholesterol depressant activities of oils from the standpoint of fish oils, which appeared to be more potent than vegetable oils. He concluded that the iodine number was "quite unreliable" as an indicator of cholesterol-depressant activity, and that degrees of "saturation" or "unsaturation" had little meaning because of the great differences in FA

structure and composition that were not revealed by this classification.

Kritchevsky et al. (247) fed young male rabbits a variety of vegetable oils, not including soybean oil, additionally 2% of cholesterol, for eight weeks. They then examined the aortas biochemically and histologically. Under those conditions the authors concluded that arachidic and behenic acids were responsible for the greater part of the atherogenesis observed, but acknowledged that other factors such as triglyceride structure might have had an important role.

V. Drug Interactions

No reports were found relating to soybean oil and drug interactions. It should be noted that fat-soluble substances used as drugs will become dissolved in soybean oils as in other oils, and if hydrogenated oil is used, they will be absorbed to the extent that the oil is absorbed; for example, if only 65% of a highly hydrogenated oil is absorbed, only that percentage of the drug given will probably be utilized.

VI. Consumer Exposure

Statistics are shown in Table 14-15. No separate statistics were found for hydrogenated soybean oils.

As of 1971 the major use of soybean oil was in shortenings (Table 14), and it can be presumed that most of this was hydrogenated. However, as already noted (see Description) the degree and processes of hydrogenation are by no means uniform.

Equally variable are the products described as soybean oil that are incorporated into prepared foods (Table 15), and their contributions to the lipid contents of those foods. Examples of this may be seen in Melnick et al. (295), and Bisno (054).

The second major use of soybean oils is in margarine (Table 14). The FDA Standard of Identity for Oleomargarine or Margarine (030) permits the use of partly hydrogenated soybean oil, and currently margarines contain about 75% of these oils. Overseas the recommended standard (084) is somewhat wider than in the United States, and margarines contain less of hydrogenated soybean oils. Nevertheless the FAO Books In Print (136) lists no standards for hydrogenated oils as such. Therefore, the exposure of consumers to hydrogenated soybean oils, whether in the United States or elsewhere, is unknown.

In short, no information was found on consumer exposure to hydrogenated soybean oil as such, whether alone or in combination with other dietary fats, and the only certainty (assuming the statistics to be reliable) is that it can not be more than the maximum overall production and intake data for all soybean oils (Tables 14, 15).

Table 14

Production and Overall Use of Soybean Oils

	1971	1970	1949
World production, millions tons:			
Vegetable, animal, marine oils	41.373	39.236	
Vegetable oils	20.505	19.545	
Soy oil	6.155	5.960	
USA total of fats and oils, millions lbs:			
Food use	11,009	11,161	6,419
Non-food use	5,383	5,675	3,735
Millions acres under soybeans:			
World	74.617		
USA	43.176*		
China	19.768		
Brazil	4.568		
USSR (no other country over 2 million acres)	2.162		
USA soybean oil production:			
Millions bushels soybeans crushed		761.265	
Millions lbs oil produced+		8,261*	1,937
Shipments and exports, millions lbs		1,782*	
Exports from USA, millions lbs (approximate):			
to N. America		147	
to S. America		219	
to Europe		305	
to Africa		211	
to Asia		870	
to Oceania		8.5	
Imports into USA of soybean oil, all from Denmark: thousands of lbs (1969 46,087 lbs; 1965 Nil)	37.452		
Soybean oil prices per lb: crude, in USA Midwest		12.9¢	12.3¢
edible, in tanks at New York		15.6¢	16.6¢

* A record amount

* Yield 27.6 bushels/acre*, contrasted with 13.3 bushels/acre in 1929.

\+ The level of stocks in 1970 was 543 million lbs, comparable to other years.

Table 14 (cont.)

Production and Overall Use of Soybean Oils

	1971	1970	1949
USA margarine production, millions lbs:			
Total	1,831	1,794	701
Soybean oil content**	1,385	1,410	257
USA shortening production, millions lbs:			
Total	3,479	3,599	1,494
Soybean oil content***	2,047	2,182	713

** Cottonseed oil is the main other ingredient, e.g., 431 million lbs in 1949.

*** Other ingredients are listed as including lard, beef fat, and negligible quantities of fish oils.

These data, except for imports in USA, are abstracted from Agricultural Statistics, 1972, US Government Printing Office, Washington, D.C. The data on imports are abstracted from U.S. Imports for Consumption and General Imports, US Department of Commerce, Bureau of the Census, publications FT 246-71, FT 246-69, and FT 246-65, US Government Printing Office, Washington, D.C.

Table 15

Incorporation of Soybean Oils in Particular Foods
And Average USA Daily Intakes

A. Extracts from Comprehensive GRAS Survey, 1972, NAS NRC, Washington, D.C.

Usage levels of soybean oil reported by industry (from Table 5)

Food category No.	Name	Percent use, weighted means: Usual	Maximum
01	Baked goods (R)	4.8	4.8
03	Other grains (R)	1.0	1.0
04	Fats and oils (R)	60.5	62.5
14	Processed vegetable (R)	0.5	0.9
25	Nut products (R)	9.0	11.0
30	Hard candy (R)	0.2	0.2
83	Formulas (B)	4.1	4.4

R = regular food, B = baby food.

B. Importance of soybean oil for technical effects and/or flavor, as rated by industry (Table 9)

Use category No.	Name	Percent importance rating: A	B	C
05	Dough conditioner	100	0	0
07	Emulsifier	66.7	0	33.3
13	Formula aid	0	100	0
19	Nutrient supply	50	0	50
30	Texturizer	0	100	0
73	Hard candy	0	0	0

Ratings: A = "essential", e.g., flavor or effect unobtainable with any other substance than soybean oil.
B = "important", e.g., alternatives either inordinately expensive or give inferior results.
C = "useful", e.g., soybean oil is replaceable with alternatives.
"Percent" is either the percent of situations in which soybean oil is currently used, or the percent of soybean oil in the mixtures currently used for the purposes described.

Table 15 (cont.)

C. Potential daily intakes, in milligrams of soybean oil, by age-cohorts of the US population, from various food categories (Table 15)

Food category No.	Name	Age cohorts: 0-5 months	6-11 months	12-23 months	2-65 years
03	Other grains (R)	89 186	181 415	199 397	342 673
04	Fats and oils (R)	2,965 8,088	2,481 5,188	3,933 7,563	10,769 19,875
14	Processed vegetables (R)	41 138	151 517	202 578	428 1,262
25	Nut products (R)	36 55	999 2,385	522 1,485	981 2,607
30	Hard candy (R)	0 0	1 2	3 6	7 15
83	Formulas (B)	16,329 29,003	11,838 27,088	14,538 33,042	0 0
Calculated totals of above		19,460 38,070	15,651 35,595	19,397 43,071	12,527 24,432

Two estimates are given at each plot - "usual" and "very high", derived as follows:
"Usual" = average usage level in food, mean food consumption estimates.
"Very high" = maximal usage level in food, maximal food consumption estimates.
Two intermediate values are given in Table 15 - "High A" or maximal usage level, mean consumption; and "High B" or average usage level, maximal consumption. Low or minimal levels are not given in Table 15 or in other Tables in this survey. Thus the figures given above show the range from "average" actual intakes to maximal potential intakes, as estimated by the food industry.

1 Aaes-Jorgensen, E. . 1954
The role of fat in the diet of rats. 6. Influence on growth of various fats in ordinary refined state and after hydrogenation or polymerization
Thesis. Copenhagen

2 Aaes-Jorgensen, E. and O.S. Privett. 1959
Biochemistry of lipids
Pergamon Press, Oxford

3 Aaes-Jorgensen, E. 1961
Essential fatty acids.
Physiol. Rev. 41:1-51

* 4 Aaes-Jorgensen, E. 1961
Hydrogenated oils and polyunsaturated fatty-acid isomers in nutrition
Proc. Nutr. Soc. 20:156-163

5 Aaes-Jorgensen, E. 1965
Biochemical aspects of hydrogenated oils and isomeric unsaturated fatty acids in nutrition.
Nutrition et Dieta 7:130-134

6 Aaes-Jorgensen, E. 1966
Unsaturated fatty acid isomers in nutrition
Nutr. Rev. 24:1-5

* 7 Aaes-Jorgensen, E. 1967
Fish oils as a source of essential fatty acids
In, Fish Oils, M.E. Stansby (Ed.), AVI Publishing Co., Westport, Conn. pp. 300-321

* 8 Aaes-Jorgensen, E., and G. Holmer. 1969
Essential fatty acid-deficient rats: I. Growth and testes development
Lipids 4:501-506

9 Aaes-Jorgensen, E., O.S. Privett and R.T. Holman. 1959
Essential fatty acid activities of hydrocarbons and alcohols analogous to linoleate and linolenate.
J. Nutr. 67:413-421

10 Aaes-Jorgensen, E., O.S. Privett, and R.T. Holman. 1959
Essential fatty acid deficiency in rats,
In "Biochemistry of Lipids", Pergamon Press, Oxford 136-142

11 Ahrens, E.H., Jr., T.T. Tsaltas, J. Hirsch and W. Insull, Jr. 1955
Effects of dietary fats on the serum lipids of human subjects
J. Clin. Invest. 3: 918

12 Ackert, J.E. 1947
Soybean oil meal supplement effective in maintaining host resistance to ascarids
Kuba 3:92-94

* 13 Ackman, R.G. S.N. Hooper and J. Hingley. 1971
Monoethylenic fatty acids of a partially hydrogenated herring oil.
J. Am. Oil Chem. Soc. 41:804-806

14 Adamstone, F'B' J'L' Krider and M'F' James. 1949
Response of swine to vitamin E deficient rations
Ann. N'Y' Acad. Sci. 52 260

15 Ahrens, E.H., J. Hirsch, W. Insull, Jr., T.T. Tsaltas, R. Blomstrand and M.L. Peterson. 1957
The influence of dietary fats on serum lipid levels in man
Lancet 1: 943

16 Ahrens, E.H., Jr. W. Insull, Jr., J. Hirsch, W. Stoffel, M.E. Peterson, J.W. Farquhar, T. Miller and H.J. Thomasson. 1959
The effect on human serum-lipids of a dietary fat, highly unsaturated, but poor in essential fatty acids
Lancet 115-119

17 Albrink, M.J. and E.B. Mann. 1959
Serum triglycerides in coronary artery disease.
Arch. Intern. Med. 103:4-8

18 Alexander, J.C. 1966
Effect on diet handling on nutritional studies with used frying fats
Lipids 1: 254-257

19 Alfin-Slater, R'B'. 1961
Factors affecting essential fatty acids utilization
In, Drugs Affecting Lipid Metabolism, S. Garattini and R' Paoletti (Eds.), Elsevier, Amsterdam

20 Allen, R.R. 1960
Hydrogenation
J. Am. Oil Chem. Soc. 37: 521-523

21 Allen, R.R. 1962
Practical aspects of hydrogenation
J. Am. Oil Chem. Soc. 39: 457-459

* 22 Altman, P.L. and D.S. Dittmer (Editors). 1972
Biology Data Book, 2nd Edition
Federation of American Societies for Experimental Biology, Bethesda, Maryland
Vol. 1:300-317, 340-352

23 Ambrose, A'M' D'J' Robbins and F. Deeds. 1958
Effects of acetostearin on reproduction in albino rats
Food. Res. 23 550

24 American Medical Association Council on Food and Nutrition. 1962
The regulation of dietary fat
J. Am. Med. Assoc. 181 111

25 American Oil Chemists Society. 1957
Official and tentative methods of the American Oil Chemists Society, 2nd Edition
American Oil Chemists Society, Chicago, Illinois

* 26 American Pharmaceutical Association. 1970
National Formulary, 13th Edition
American Pharmaceutical Association, Washington, D.C.

27 Anderson, J.T., F. Grande and A. Keys. 1961
Hydrogenated fats in the diet and lipids in the serum of man
J. Nutr. 75: 388

28 Andrews, J.S., J.F. Mead and W.H. Griffith. 1956
Toxicity of lipid peroxides in the rat
Fed. Proc. 15: 918

* 29 Andrews, J.S., W.H. Griffith, J.F. Mead, and R.A. Stein. 1960
Toxicity of air-oxidized soybean oil
J. Nutr. 70:199-210

* 30 Anon. 1973
FDA Standard of Identity for oleomargarine or margarine, Code of Federal Regulations
Fed. Regist. Title 21, Chap. I, Part 45

31 Ansell, G.B. and J.N. Hawthorne. 1964
Phospholipids
Elsevier Publishing Co., Amsterdam p. 56

32 Armour and Co. 1966
Preparation of liquid shortening and product
Brit. Pat. 1,040,056 issued Aug. 24, 1966

33 Armstrong, W.D., J. Van Pilsum, A. Keys, F. Grande, J.T. Anderson and L. Tobian. 1957
Alteration of serum cholesterol by dietary fats
Proc. Soc. Exp. Biol. & Med. 96: 302

34 Artman, N.R. 1964
Interactions of fats and fatty acids as energy sources for the chick
Poultry Sci. 43:994-1004

35 Association of Official Agricultural Chemists. 1965
Official Methods of Analysis of the Association of Official Agricultural Chemists E. A.O.A.C., P.O.B. 540 Benjamin Franklin, Washington, D.C.

36 Ball, E.G. 1939
Xanthine oxidase; purification and properties
J. Biol. Chem. 128: 51

37 Barnes, R.H., W.O. Lundberg, H.T. Hanson and G.O. Burr. 1943
The effect of certain dietary ingredients on the keeping quality of body fat
J. Biol. Chem. 149: 313-322

38 Bauer, Clifford D., Gerald L. Neuser, and Hamilton A. Pinkalla. 1968
Low-fat margarines
Fr. Pat. 1,540,629 issued Jan. 49, 1968

39 Baumann, W.J. and H.K. Mangold. 1964
Reactions of aliphatic methanesulfonates. I. Syntheses of long-chain glyceryl-(1) ethers
J. Org. Chem. 29: 3055-3057

40 Baumann, W.J., H.H.O. Schmid, H.W. Ulshofer and H.K. Mangold. 1967
Alkoxylipids. IV. Synthesis and characterization of naturally occurring ethers, esters and ether-esters of diols
Biochim. Biophys. Acta. 144: 355-365

* 41 Beal, R.E., K.J. Moulton, H.A. Moser, and L.T. Black. 1959
Removal of copper from hydrogenated soybean oil
J. Am. Oil Chem. Soc. 46(9):498-500

* 42 Beare, J.L. 1961
The influence of dietary fat on the fatty acid composition of liver, carcass and milk of rats
Can. J. Biochem. Physiol. 39:1855-1863

43 Beezhold, F.L., and V.F. Stout. 1973
The use and effect of mixed standards on the quantitation of polychlorinated biphenyls
Bull. Environ. Contam. Toxicol. 10(1)

44 Bell, E'R' J'H' Raley, F'F' Rust, F'H' Seubold and W'E' Vaughan. 1951
Reactions of free radicals associated with low temperature oxidation of paraffins
Discussions Faraday Soc. 10

45 Bell, Richard J., and Robert L. Campbell, Jr. 1967
Coatings and their manufacture for ice cream and frozen desserts
U.S. Pat. 3,333,968 issued Aug. 1, 1967

* 46 Bell, Richard J., Robert L. Campbell, Albert E. Brust, and Lloyd R. Custer (Anderson,. 1969
Liquid shortening manufacture
U.S. Pat. 3,455,699 issued Jul. 15, 1969

47 Bennett, R.D. and E. Heftmann. 1963
Devices for continuous development and sample application in preparative thin-layer chromatography
J. Chromatogr. 12: 245-248

48 Bernheim, F., K.H. Wilbur and C.B. Kenaston. 1952
The effect of oxidized fatty acids on the activity of certain oxidative enzymes
Arch. Biochem. Biophys. 38: 177-184

* 49 Bernsohn, J., and L.H. Stephanides. 1967
Aetiology of multiple sclerosis
Nature 215:821-823

50 Best Foods, Inc. 1953
Soybean-oil compositions
U.S. Pat. 2,627,469 issued Feb. 3, 1953

51 Beveridge, J.M.R. and W.F. Connell. 1962
The effect of commerical margarines on plasma cholesterol levels in man
Am. J. Clin. Nutr. 10: 391

52 Beveridge, J.M.R., W.F. Connell and G.A. Mayer. 1956
Dietary factors affecting the level of plasma cholesterol in humans: the role of fat
Can. J. Biochem. Physiol. 34: 441

53 Beveridge, J.M.R., W.F. Connell, G.A. May, J.B. Firstbrook and M.S. DeWolfe. 1955
The effects of certain vegetable and animal fats on the plasma lipids of humans
J. Nutr. 56: 3

* 54 Bisno, Lou. 1950
Some considerations in commercial pie baking. II
Baker's Dig. 24(2):31-34

* 55 Blaxter, K.L., F. Brown, W.A. Wood and A.M. MacDonald. 1953
The nutrition of the young Ayshire calf. 14. Some effects of natural and synthetic antioxidants on the incidence of muscular dystrophy induced by cod-liver oil
Brit. J. Nutr. 7:337-349

56 Blaxter, K'L' P'S Watts and W'A' Wood. 1952
The nutrition of the young Aryshire calf. 8. Muscular dystrophy in the growing calf
Brit. J. Nutr. 6 125

57 Bloch, J. 1964
The importance of unsaturation to life
In, Metabolism and Physiological Significance of Lipids, R'M'C' Dawson and D'M' Rhodes (Eds.), John Wiley and Sons, London

58 Boekenoogen, H.A. 1964
Analysis and Characterization of Oils, Fats and Fat Products
Interscience Publishers, London

59 Bohstedt, G' J'M' Fargo and W'A' King. 1938
Soybean oil meal and other plant protein for pigs supplemented with limestone and bonemeal
Proc. Am. Soc. Anim. Prod. 30 107-110

60 Bolland, J'L'. 1946
Kinetic studies in the chemistry of rubber and related materials. I' The thermal oxidation of ethyl linoleate
Proc. Roy. Soc. (London) 186A 218-236

* 61 Booth, A.N., E.M. Bickoff and G.O. Kohler. 1960
Estrogen-like activity in vegetable oils and mill by-products
Science 131:1807

62 Bortz, W., S. Abraham and I.L. Chaikoff. 1963
Localization of the block in lipogenesis resulting from feeding fat
J. Biol. Chem. 238: 1266

63 Bozian, R'C' and J'G' Coniglio. 1962
The effect of ethyl arachidonate upon the metabolism of oleic acid in the fat deficient rat
Fed. Proc. 21 286

* 64 Brenner, R.R., and R.O. Peluffo. 1966
Effect of saturated and unsaturated fatty acids on the denaturation in vitro of palmitic, stearic, oleic, linoleic and linolenic acids
J. Biol. Chem. 241(22):5213-5219

65 British Standards Institution . 1958
Methods of Analysis of Oils and Fats
British Standard House, 2 Park St., London, W. I Y. YAA, England British Standard 684:1958

66 Brockerhoff, H., R.J. Hoyle and K. Ronald. 1964
Retention of the fatty acid distribution pattern of a dietary triglyceride in man
J. Biol. Chem 239: 735-739

67 Brockmann, H. 1949
Chromatography of colorless substances and the relation between constitution and adsorption affinity
Discuss. Faraday Soc. 7: 58-64

68 Brohult, A. 1956
Alkoxyglycerols and their use in radiation treatment
Acta Radiol., Stockh., Suppl. 223 7-99

69 Bronte-Stewart, B'A' A' Antonis, L. Eales and J'F' Brock. 1956
Effects of feeding different fats on serum cholesterol levels
Lancet i 521-530

70 Buchi, G. and N.C. Yang. 1955
Organic reactions catalyzed by light. 3. Cis-alpha ionone.
Helv. Chim. Acta. 38: 1338-1341

71 Bunnell, R.H., L.D. Matterson, E.P. Singsen, L.M. Potter, A. Kozeff and E.L. Jungherr. 1955
Studies on encephalomalacia in the chick. 3. The influence of feeding or injecting various tocopherols and other antioxidants on the incidence of encephalomalacia
Poultry Sci. 34: 1068

72 Burr, G.O. M.M. Burr, and W.R. Brown. 1930-1931
On the nutritive value of certain oils
Proc. Soc. Exp. Biol. Med. 28:905-907

73 Burr, G.O., M.M. Burr, and W.R. Brown. 1930-1931
On the nutritive value of certain oils
Proc. Soc. Exp. Biol. Med. 28: 905-907

74 Burr, G'O' and M'M' Burr. 1929
A new deficiency disease produced by the rigid exculsion of fat from the diet
J. Biol. Chem. 82 345-367

75 Burr, G'O' and M'M' Burr. 1930
On the nature and role of the fatty acids essential in nutrition
J. Biol. Chem. 86 587-621

76 Burton, R.M. 1964
Gangliosides and Acetylcholine of the Central Nervous System
Biochim Biophys. Acta. 84:441-447

77 Carr, C.J., H.F. Sassoom, and K.D. Fisher. 1973
A study of the potential applications of olfactory research in man
Contract DAHC 19-72-C-0010, LSRO FASEB for Department of the Army, Washington, D.C.

78 Century, B' and M'K' Horwitt. 1960
Role of diet lipids in the appearance of dystrophy and creatinuria in the vitamin E-deficient rat
J. Nutr. 72 357

79 Century, B' M'K' Horwitt and P. Bailey. 1959
Lipid factors in the production of encephalomalacia in the chick
Arch. Gen. Psychiat. 1 420

80 Chakrabarty, K. and G.A. Leveille. 1969
Acetyl-CoA carboxylase and fatty acid synthetase activities in liver and adipose tissue of meal-fed rats
Proc. Soc. Exp. Biol. Med. 131: 1051

* 81 Chang, S.S. 1967
Processing of fish oils
In, Fish Oils, M.E. Stansby (Ed.), AVI Publishing Co., Westport, Conn. pp. 206-221

* 82 Chipault, J.R. 1959
The odors of oxidized fish oils
Annu. Rept., Hormel Inst., 1958-1959 pp. 7-9

* 83 Codex Alimentarius Commission. 1969
Recommended international general standard for edible fats and oils not covered by individual Codex standards
Joint FAO;WHO Food Standards Programme, Codex Alimentarius Commission, Food and Agriculture Organization of the United Nations
CAC;RS 19-1969

* 84 Codex Alimentarius Commission. 1969
Recommended international standard for margarine
Joint FAO;WHO Food Standards Programme, Codex Alimentarius Commission, Food and Agriculture Organization of the United Nations
CAC;RS 32-1969

* 85 Codex Alimentarius Commission. 1969
Recommended international standard for edible soya bean oil
Joint FAO;WHO Food Standards Programme, Codex Alimentarius Commission, Food and Agriculture Organization of the United Nations
CAC;RS 20-1969

86 Coenen, J.W.E. 1960
Rate studies of the selective hydrogenation of fatty oils
Actes du IIe congres international de catalyse, Paris Tome II: 2705-2731

87 Coenen, J.W.E., H. Boerma, B.G. Linsen and B. de Vries. 1964
Selectivity in fatty oil hydrogenation. Influence of catalyst pore structure on selectivity characteristics
Proc. 3rd International Congress on Catalysis, Amsterdam

* 88 Committee on Specifications. 1972
Food Chemicals Codex
Committee on Food Protection, National Academy of Sciences, National Research Council, Washington, D'C'

* 89 Cowan, J.C., C.D. Evans, H.A. Moser, G.R. List, S. Koritala, K.J. Moulton, and H.J. Dutton. 1970
Flavour evaluation of copper-hydrogenated soybean oils
J. Am. Oil Chem. Soc. 47(12):470-474

90 Crampton, E.W., F.A. Farmer and F.M. Berryhill. 1951
The effect of heat treatment on the nutritional value of some vegetable oils
J. Nutr. 43: 431-440

91 Crampton, E.W., R.H. Common, E.T. Pritchard and F.A. Farmer. 1956
Studies to determine the nature of the damage to the nutritive value of some vegetable oils from heat treatment. IV. Ethyl esters of heat-polymerized linseed, soybean and sunflower seed oils
J. Nutr. 60: 13-24

92 Crampton, E.W., R.H. Common, F.A. Farmer, A.F. Wells and D. Crawford. 1953
Studies to determine the nature of the damage to the nutritive value of some vegetable oils from heat treatment. III. The segregation of toxic and non-toxic material from the esters of heat-polymerized linseed oil by distillation and by urea
J. Nutr. 49: 333-346

93 Crampton, E.W., R.H. Common, F.A. Farmer, F.M. Berryhill and L. Wiseblatt. 1951
Studies to determine the nature of the damage to the nutritive value of some vegetable oils from heat polymerization. I. The relation of autoxidation to decrease in the nutritional value of heated linseed oil
J. Nutr. 43: 533-539

94 Crampton, E'W' R'H' Common, F'A' Farmer, F'M' Berryhill and L. Wiseblatt. 1951
Studies to determine the nature of the damage to the nutritive value of some vegetable oils from heat treatment. II' Investigation of the nutritiousness of thermal polymerization of linseed oil
J. Nutr. 44 177-189

95 Crane, Olive, and Thos. E. Hollingshead. 1938
Einige praktische massnahmen zur wahl des kunstspeisefettes fur biskuits und anderes geback
Oil Soap 15:43-44

96 Crockett, M.E. and H.J. Deuel, Jr. 1947
A comparison of the coefficient of digestibility and the rate of absorption of several natural and artificial fats as influenced by melting point
J. Nutr. 33: 187-194

97 Crossley, A' T'D' Heyes and B'J'F' Hudson. 1962
The effect of heat on pure triglycerides
J. Am. Oil Chem. Soc. 30 9

98 Dam, H. and H. Granados. 1947
The influence of certain substances on massive hepatic necrosis and lung hemorrhage in rats fed low-protein, vitamin E deficient diets
Acta Pharmacol. Toxicol. 7 181

* 99 Dam, H. 1957
Influence of antioxidants and redox substances on signs of vitamin E deficiency
Pharmacol. Rev. 9:1-16

100 Dam, H., H. Granados and I. Prange. 1949
Influence of two different fats on reproduction capacity of vitamin E deficient rats
Acta. Physiol. Scand. 18: 161

101 Dam, H., H. Granados and L. Maltesen. 1950
Changes in the mineral composition of enamel and dentin of the incisors in vitamin E deficient rats
Acta. Physiol. Scand. 21: 124-130

102 Dam, H., I. Kruse, I. Prage and E. Sondergaard. 1948
Influence of dietary ascorbic acid, nordihydroguaiaretic acid and cystine on vitamin E deficiency symptoms in chicks
Biochim. Biophys. Acta 2: 501

103 Dam, H., I. Kruse, I. Prage and E. Sondergaard. 1951
Substances affording a partial protection against certain vitamin E deficiency symptoms
Acta. Physiol. Scand. 22: 299

104 Dam, H., I. Prange and E. Sondergaard . 1952
Muscular degeneration (white striation of muscles) in chicks reared on vitamin E deficient low fat diets
Acta. Path. Microbiol. Scand. 31: 172-184

* 105 Dam, H., I. Prange and F. Christensen. 1965
Alimentary production of gallstones in hamsters. 17. Influence of butter fat and the fat of dietetic margarine rich in linoleic acid on gallstone formation and composition of the bladder bile
Z. Ernaehrungwiss. 6(2-3):97-106

106 Dam, H., J. Glavind, O. Berath and E. Hagens. 1938
Anti-encephalomalacia activity of di-alpha-tocopherol
Nature 142: 1157

107 Dam, H' and H. Granados. 1949
Peroxidation of body fat in vitamin E deficiency
Acta Physiol. Scand. 10 162-171

108 Darragh, Richard T., and Kenneth W. Nelson (Proctor and Gamble Co.). 1968
All-purpose glyceride shortening composition
U.S. Pat. 3,397,996 issued Aug. 20, 1968

* 109 Deck, R.E., and K.K. Kaiser. 1970
Analytical method for determining copper in edible shortenings and oils
J. Am. Oil Chem. Soc. 47:126-128

110 Deuel, H., Jr. 1954
Progress in the chemistry of fats and other lipids
Pergamon Press LTD, London Vol. 2

111 Deuel, H.J., Jr. 1951
The Lipids
Interscience Publishers, New York

112 Deuel, H.J., Jr., L.P. Hallman and A. Reifman. 1941
The rate of absorption of various fatty acids by the rat
J. Nutr. 21: 373-382

* 113 DeJonge, A., J.W.E. Coenen and C. Okkerse. 1965
Selective hydrogenation of linolenate groups in soya-bean oil
Nature 206:573-574

* 114 DeKoning, A.J. and M.H. Silk. 1963
The 2-thiobarbituric acid reagent for determination of oxidative rancidity in fish oils.
J. Am. Oil Chem. Soc. 40:165-169

115 Diehl, H. and G.F. Smith. 1958
The copper reagents: copper neuropreine bathoeupreine.
The G. Frederick Smith Chemical Company, Columbus, Ohio

116 Dobson, Robert D., Louis H. Going, and Eddy R. Hair (Proctor and Gamble Co.). 1969
Glyceride fat tablets containing additives for frying fats
U.S. Pat. 3,449,133 issued Jun. 10, 1969

* 117 Dror, Y., H.F. Sassoon, J.J. Watson, D.O. Mack, and B.C. Johnson. 1973
Fat versus sucrose as the nonprotein calorie portion of the diet of rats
J. Nutr. 103:342-346

118 Eckey, E.W. 1954
Vegetable Fats and Oils
Reinhold, New York

119 Eggert, R.O., E. Patterson, W.T. Akers and E.L.R. Stokstad. 1957
The role of vitamin E and selenium in the nutrition of the pig
J. Anim. Sci. 16: 1037

* 120 Egwim, P.O. and D.S. Sgoutas. 1972
Effect of hydrogenated soybean fat on rat adipose tissue and on liver acetyl-CoA carboxylase and fatty acid synthetase activities.
Am. J. Clin. Nutr. 25:16-22

121 Eley, D.D. 1955
Catalysis
P.H. Emmet (Ed.), Reinhold Publishing Corporation, New York Vol. 3, 50

122 Ellis, C. 1930
Hydrogenation of Organic Substances
D. Van Nostrand Co., Inc., New York
3rd Ed., p. 22, 184, 866

123 Ellis, Carleton. 1927
Hydrierung von ol
U.S. Pat. 1,645,377 issued Oct. 11, 1927

* 124 Erickson, B.A., R.H. Coots, F.H. Mattson, and A.M. Kligman. 1964
The effect of partial hydrogenation of dietary fats, of the ratio of polyunsaturated to saturated fatty acids, and of dietary cholesterol upon plasma lipids in man
J. Clin. Invest. 43(11):2017-2025

* 125 Erlandsen, L. 1938
On the chemistry of butter and margarine (German)
Fette, Seifen 45 215-219

* 126 Ershoff, B.H. 1960
Effects of diet on fish oil toxicity in the rat
J. Nutr. 71:45-53

127 Evans, H'M' and G'A' Emerson. 1913
The prophylactic requirement of the rat for alpha tocopherol
J. Nutr. 26 555

128 Farmer, F'A' B'C' Mutch, J'M' Bell, L'D' Woolsey and E'W' Crampton. 1950
The vitamin E requirement of guinea pigs
J. Nutr. 42 309

129 Farquhar, J.W., W. Insull, Jr., P. Rosen, W. Stoffel and E.H. Ahrens, Jr. 1959
The analysis of fatty acid mixtures by gas-liquid chromatography: Construction and operation of an ionization chamber instrument
Nutrition Reviews (Supplement) 17: 1-30

130 Fernald, M.L.,. 1950
Gray's Manual of Botany
Ed. 8 American Book, New York

* 131 Feuge, R.O. and A.E. Bailey. 1944
Measurement of the consistency of plastic vegetable fats-a standard micropenetration technique
Oil Soap 21(3):78-84

132 Fiich, C'D' and J'S' Dinning. 1963
Vitamin E deficiency in the monkey. V. Estimated requirements and the influence of fat deficiency and anti-oxidants on the syndrome
J. Nutr. 79 69

133 Filer, L'J' Jr., R'E' Rumery and K'E' Mason. 1946
Specific unsaturated fatty acids in the production of acid-fast pigment in the vitamin E deficient rat and the protective action of tocopherols
In, Biological Antioxidants, Trans. of the 1st Conf., C'G' MacKenzie (Ed.), Josiah Macy, Jr., Found., New York Oct. 10-11, 1946, p. 67

* 134 Fineberg, H., and A.G. Johanson. 1967
Industrial use of fish oils
In, Fish Oils, M.E. Stansby (Ed.), AVI Publishing Co., Westport, Conn. pp. 222-238

135 Folch, J.; Lees, M. and Sloane-Stanley, G.H. 1957
A simple method for the isolation and purification of total lipids from animal tissues
J. Biol. Chem. 226:497

* 136 Food and Agriculture Organization of the United Nations. 1973
FAO book in print pp. 66-69

137 Food Protection Committee. 1972
Comprehensive Survey of Substances Generally Regarded as Safe
National Academy of Sciences, National Research Council, Washington, D.C.

138 Franke, K.W. 1934
A new toxicant occurring naturally in certain samples of plant foodstuffs. I. Results obtained in preliminary feeding trials
J. Nutr. 8: 597-609

139 Frommhold, Karl (Unilever N.V.). 1969
Margarine composition
Fr. Pat. 2,002,841 issued Oct. 30, 1969

140 Gaddis, A'M' R' Ellis and G'T' Currie . 1961
Carbonyls in oxidizing fat. V. The composition of neutral volatile monocarbonyl compounds from autoxidized oleate, linoleate-linolenate esters and fats
J. Am. Oil Chem. Soc. 38 371

141 Gatt, S. and M.M. Rapport. 1965
Hydrolysis of ceramide lactoside and ceramide glucoside by glycosidases from brain.
Israel J. Med. Sci. 1:624-627

142 Gershoff, S'N' and S'A' Norkin. 1962
Vitamin E deficiency in cats
J. Nutr. 77 303-308

* 143 Gilder, S.S. 1968
The heart and soya bean oil
Can. Med. Assoc. J. 99:1211

* 144 Gill, A.H. and Yu M. Ma. 1928
The hydrogenation of soybean oil.
Oil and Fat Industries 5:348-351

145 Glavind, J., S. Hartmann, J. Clemmesen, K.E. Jessen and H. Dam. 1952
Studies on the role of lipoperoxides in human pathology. II. The presence of peroxidized lipids in the atherosclerotic aorta
Acta. Path. Microbiol. Scand. 30: 1-6

146 Goettsch, M'. 1942
Alpha-tocopherol requirement of the mouse
J. Nutr. 23 513

* 147 Gooding, C.M.B. 1966
Fate of chlorinated organic pesticide residues in the production of edible vegetable oils
Chem. Ind. 1966(Week 8):344

148 Gordon, H., B. Lewis, L. Eales, and J.F. Brock. 1957
Dietary fat and cholesterol metabolism. Fecal elimination of bile acids and other lipids
Lancet 2: 1299

149 Gottenboss, J.J. and H.J. Thomasson. 1965
The biological action of hardened oils
Nutrictio et Dieta 7: 110-129

150 Graham, C.E. and W.H. Griffith. 1910-1911
Observations on the nutritive value of certain fats
Proc. Soc. Exp. Biol. Med. 28:756-758

151 Grasso, S., B. Gunning, K. Imaichi, G. Michaels and L. Kinsell. 1962
Effects of natural and hydrogenated fats of approximately equal dienoic acid content upon plasma lipids
Metabolism 11: 920

152 Greenberg, D'M' C'E' Calbert, E'E' Savage and H'J' Deuel. 1950
The effect of fat level of the diet on general nutrition. VI' The interrelation of linoleate and linolenate in supplying the essential fatty acid requirement in the rat
J. Nutr. 41 473

153 Griffiths, T'W'. 1961
Studies on the requirement of the young chick for vitamin E. II' The effects on different sources and levels of dietary lipids on liveweight gain and body vitamin E storage
Brit. J. Nutr. 15 271

154 Grobfeld, J. and J. Peter. 1934
Nachweis von Margarine und gehärteten Olen in Lebensmitteln
Z. Unters. Lebensmittel 68: 345-358

155 Grobfeld, J. 1930
Die Verseifungszahl der Speisefette als Funktion des Gehaltes an Palmitinsaure und anderen Fettsauren
Z. Unters. Lebensmittel 60: 64-92

156 Grobfeld, J. 1936
Prufung auf Butter and Margarine fett in der Lebensmittelkontrolle
Fette u. Seifen 43: 100-103

* 157 Grollman, A. 1945
The preparation of extracts from oxidized marine and other oils for reducing the blood pressure in experimental and human chronic hypertension
Pharm. & Exp. Therap. 84:128-135

* 158 Grover, P. 1973
How polycyclic hydrocarbons cause cancer
New Scientist 58(850):685-687

159 Gyorgy, P' H' Goldblatt and M. Ganzin. 1959
Dietary fat and cirrhosis of the liver
Gastroenterol. 37 637

160 Haighton, A.J. 1959
The measurement of the hardness of margarine and fats with cone penetrometers
J. Am. Oil Chemists' Soc. 36: 345-348

161 Haighton, A.J. 1963
Consistency of margarine and fats
Fette, Seifen, Anstrichmittel 65: 479-482

162 Haighton, A.J. 1965
Work-softening of margarine and shortening.
J. Am. Oil Chem. Soc. 42: 27-30

163 Hakansson, I. 1966
Physico-chemical changes in artifical fat emulsions during storage. Studies of the hydrolysis and its physiological effects
Acta Chem. Scand. 20(8):2267-2281

* 164 Hamberg, M., and B. Samuelsson. 1967
On the specificity of the oxygenation of unsaturated fatty acids catalyzed by soybean lipoxidase
J. Biol. Chem. 242(22):5329-5335

165 Hanahan, D.J., J. Ekholm and C.M. Jackson. 1963
Studies on the structure of glyceryl ethers and the glyceryl ether phospholipids of bovine erythrocytes
Biochemistry 2: 630-641

* 166 Handschumaker, E., S.W. Thompson, and J.E. McIntyre. 1943
Detection and estimation of dipalmito and distearo glycerides in hydrogenated oils
Oil Soap 20:133-134

* 167 Hannewijk, J. 1967
Use of fish oils in margarine and shortening
In, Fish Oils, M.E. Stansby (Ed.), AVI Pubishing Co., Westport, Conn. pp. 251-269

168 Harris, L'A' and H'S' Olcott. 1966
Reaction of aliphatic tertiary amines with hydroperoxides
J. Am. Oil Chem. Soc. 43 11-14

* 169 Harris, P.L., and N.D. Embree. 1963
Quantitative consideration of the effect of polyunsaturated fatty acid content of the diet upon the requirements for vitamin E
Am. J. Clin. Nutr. 13:385-392

170 Harris, P'L' E'G' Hardenbrook, F'P' Dean, E'R' Cusack and J'L' Jensen. 1961
Blood tocopherol values in normal human adults and incidence of vitamin E deficiency
Proc. Soc. Exp. Biol. Med. 107 381

171 Harris, P'L' M'L' Quaife and W'J' Swanson. 1950
Vitamin E content of foods
J. Nutr. 40 367

172 Hartree, E'F'. 1964
Metabolism of plasmalogens
In, Metabolism and Physiological Significance of Lipids, Dawson and Rhodes (Eds.), John Wiley, New York pp. 205-218

* 173 Hartwell, G.A. 1938
LX. A note on the digestion of fats by pancreatic lipase
Biochem. J. 32:463-466

* 174 Haven, F.L. 1936
The effect of cod-liver oil on tumor growth
Am. J. Cancer 27:95-98

175 Hayward, J.W., H. Steenbock, and G. Bohstedt. 1936
Effect of heat as used in extraction of soy bean oil upon nutritive value of protein of soy bean oil meal
J. Nutr. 11:219-234

176 Heesch, A. 1963
Modern margarine making
Fette, Seifen, Anstrichmittel
65: 125-137, 205-214

177 Henick, A'S' M'F' Benica and J'H' Mitchell. 1954
Estimating carbonyl compounds in rancid fats and foods
J. Am. Oil Chem. Soc. 31 88

178 Heuser, G.F., and L.C. Norris. 1944
Soybean oil meal in chick rations
Cornell Univ. Agric. Exp. Sta. Bull. (New York) 810:1-22

179 Hilditch, T.P. and E.C. Jones. 1934
Regularities in the glyceride structure of some technically important vegetable fatty oils
J. Soc. Chem. Ind. 53: 13

180 Hilditch, T.P., E.C. Jones and A.J. Rhead. 1934
The body fats of the hen
Biochem. J. 28: 786-795

181 Hill, R., J.M. Linazasoro, F. Chevallier and I.L. Chaikoff. 1958
Regulation of hepatic lipogenesis: the influence of dietary fats
J. Biol. Chem. 233: 305

182 Ho, W.H., and C.Y. Chen. 1962
Clinical observations on 107 cases of intestinal obstruction treated by soy bean oil (Chinese)
Zhong Waike Z. 10:459

183 Hoffman, J.S., R.T. O'Conner, D.C. Heinzelman and W. Bickford. 1957
A simplified method for the preparation of alpha and beta eleostearic acid and revised spectrophotometric procedure for their determination
J. Am. Oil Chem. Soc. 34: 338-342

184 Hofmann, A.F. 1964
Hydroxyapatite as an adsorbent for thin-layer chromatography: Separations of lipids and proteins
New Biochemical Separations, A.T. James and L.J. Morris (Editors) D. Van Nostrand Co., London

185 Holman, R. 1960
The ratio of trienoic: tetraenoic acids in tissue lipids as a measure of essential fatty acid requirement
J. Nutr. 70: 405-410

186 Holman, R.T. 1941
Spectrophotometric studies of the oxidation of fats. VIII. Coupled oxidation of carotene
Arch. Biochem. 21: 51-57

187 Holman, R.T. 1952
Progress in the Chemistry of Fats and Other Lipids
Holman, R.T., W.O. Lundberg and T. Malkin, (Editors) London Pergamon Press Vol. I, p. 104

* 188 Holman, R.T. 1964
Nutritional and metabolic interrelationships between fatty acids
Fed. Proc. 23:1062-1067

* 189 Holmer, G., and E. Aaes-Jorgensen. 1969
Essential fatty acid-deficient rats. III. Distribution of lipid classes in rat testes after feeding partially hydrogenated oils
Lipids 4:515-521

190 Horlick, L. and B.M. Craig. 1957
Effect of long-chain polyunsaturated and saturated fatty acids on the serum-lipids of man
Lancet 2: 566

* 191 Horlick, L. 1959
Studies on the regulation of serum cholesterol levels in man. The effects of corn oil, ethyl stearate, hydrogenated soybean oil and nicotinic acid when added to a very low fat basal diet
Lab. Invest. 8(3) 723-735

192 Horning, E.C., E.H. Ahrens, Jr., S.R. Lipsky, F.H. Mattson, J.F. Mead, D.A. Turner and W.H. Goldwater. 1964
Quantitative analysis of fatty acids by gas-liquid chromatography
J. Lipid Res. 5: 20-27

* 193 Horst, A., I. Kaganowicz, I. Zagorska, and D. Rozynkowa. 1961
Disappearance of depot fat in rats fed extremely hydrogenated oils
Am. J. Physiol. 201:617-620

* 194 Horst, A., I. Kaganowicz, I. Zagorska, and D. Rzynkowa. 1962
Effect of solidified vegetable oils on the metabolism of fats and cholesterol in man. II. Soybean oil (Pol.)
Patol. Pol. 13(2):147-157

195 Horwitt, M'K'. 1960
Vitamin E and lipid metabolism in man
Am. J. Clin. Nutr. 8 451

196 Horwitt, M'K'. 1961
Vitamin E in human nutrition--an interpretative review
Borden s Rev. Nutr. Res. 22 1

* 197 Houle, C.R. 1967
Gas-liquid chromatography
In, Fish Oils, M.E. Stansby (Ed.), AVI Publishing Co., Westport, Conn. pp. 52-62

198 Hove, E'L' and P'L' Harris. 1947
Relative activity of the tocopherols in curing muscular dystrophy in rabbits
J. Nutri 33 95

199 I.U.P.A.C. 1966
Standard Methods of the Oils and Fats section of the I.U.P.A.C.
Butterworths, London 5th Edition

* 200 Imaichi, K., K. Oyama, J. Fukuda, M. Yamazaki, and T. Hirose. 1963
Fatty acid composition of depot fat, in relation to high fish consumption in Japan
Jap. Circ. J. 29:931-936

201 Industrial Patents Corp. 1939
Stabilisieren von "oleo-ol" gegen das ranzigwerden
U.S. Pat. 2,163,912 issued Jun. 27, 1939

202 Industrial Patents Corp., Chicago. 1938
Stabilisieren von backfetten
Eur. Pat. 481,619 issued Apr. 14, 1938

203 Jansen, G.R., C.F. Hutchison and M.E. Zanetti. 1966
Studies on lipogenesis in vivo: effect of dietary fat and starvation on conversion of (14C) glucose into fat and turnover of newly synthesized fat
Biochem. J. 99: 323

204 Japikse, Cornelis H. (Procter and Gamble Co.). 1969
Emulsified salad dressings containing oleaginous gels
U.S. Pat. 3,425,843 issued Feb. 4, 1969

205 Jensen, L'S' M'L' Scott, G'F' Heuser, L'C' Norris and T'S' Nelson. 1956
Studies on the nutrition of breeding turkeys. I. Evidence indicating a need to supplement practical turkey rations with vitamin E
Poult. Sci. 35 810

206 Johnson, O.C. and F.A. Kummerow. 1957
Chemical changes which take place in an edible oil during thermal oxidation
J. Am. Oil Chem. Soc. 34: 407-409

207 Johnson, O.C., E. Perkins, M. Sugai and F.A. Kummerow. 1957
Studies on the nutritional and physiological effects of thermally-oxidized oils
J. Am. Oil Chem. Soc. 34: 594-597

208 Johnson, O.C., T. Sakuragi and F.A. Kummerow. 1956
A comparative study of the nutritive value of thermally oxidized oils
J. Am. Oil Chem. Soc. 33: 433-435

209 Johnston, W.R. and C.N. Frey. 1941
Autoxidation measurements on fatty oils using Barcroft- Warburg apparatus
Ind. Eng. Chem. (Anal. Ed.) 13: 479-481

210 Jones, E.P., C.R. Scholfield, V.L. Davison, and H.J. Dutton. 1965
Analyses of fatty acid isomers in two commercially hydrogenated soybean oils
J. Am. Oil. Chem. Soc. 42(8):727-730

211 Kaneda, T and S. Sakurai. 1954
Studies on the nutritive value of lipids. X. Seborrhea forming activity of esters of fatty acids with higher alcohol upon the rats(1)
Bull. Japan Soc. Sci. Fish. 19: 1168-1175

212 Kaneda, T. and S. Ishii. 1953
Studies on the nutritive value of lipids. VII. Nutritive value or toxicity of highly unsaturated fatty acids.
Bull. Japan Soc. Sci. Fish. 19: 174-177

213 Kaneda, T., H. Sakai and S. Ishii. 1955
Nutritive value or toxicity of highly unsaturated fatty acids
J. Biochem. (Japan) 42: 561

214 Kaneda, T., S. Sakurai and S. Ishii. 1954
Studies on the nutritive value of lipids. XI. Nutritive value or toxicity of highly unsaturated fatty acid (2)
Bull. Japan Soc. Sci. Fish. 20: 50-57

215 Kaneda, T., S. Sakurai and S. Ishii. 1954
Nutritive value or toxicity of highly unsaturated fatty acids(3)
Bull. Japan Soc. Sci. Fish. 20: 658-663

216 Kaneda, T., S. Sakurai and S. Ishii. 1957
Seborrhea forming activity of esters of fatty acids with higher alcohols upon the rats (2). Preventive methods of seborrhea
Bull. Japan Soc. Sci. Fish. 23: 324-330

217 Kanitz, H.R. 1939
Digestibility of oxidized soy bean oil (Palsgaard emulsion oil)
Z. Unters. Lebensm. 78:385-386

* 218 Karmen, A., I. McCaffrey, and R.L. Bowman. 1964
The validity of the results obtained when a stream-splitting device is used before the gas-liquid chromatography detector
J. Lipid Res. 4:108-110

219 Kaufmann, H.P. and H. Wessels. 1964
The thin-layer chromatography of fat bodies. XIV. The separation of triglycerides by combinations of adsorption and of reverse phase chromatography (in German)
Fette, Seifen, Anstrichmittel 66: 81-86

220 Kaufmann, H.P. and Z. Makus. 1960
Die Dunnschicht-Chromatographie auf dem Fettgebiet. I: Trennung von Modell-Mischangen
Fette Seifen Anstrichm. 62: 1014-1020

* 221 Kaufmann, H.P., H.K. Mangold, and K.D. Mukherjee. 1971
Chromatography of unusual lipids on thin layers of magnesium oxide
J. Lipid Res. 12(4):506-509

222 Kaufmann, H.P., Z. Makus and F. Deicke. 1961
Die Dunnschicht-Chromatographie auf dem Fettgebiet. II: Trennung der Cholesterin-Fettsaureester
Fette Seifen Anstrichm. 68: 235-238

223 Kaunitz, H., C.A. Slanetz and R.E. Johnson. 1955
Antagonism of fresh fat to the toxicity of heated and aerated cottonseed oil
J. Nutr. 55: 577-587

224 Kaunitz, H., C.A. Slanetz, R.E. Johnson and V.K. Babayan. 1961
The regulation of depot fat by linoleic acid
J. Nutr. 73: 386

225 Kaunitz, H., C.A. Slanetz, R.E. Johnson, H.B. Knight, D.H. Saunders and D. Swern. 1956
Biological effects of the polymeric residues isolated from autoxidized fats
J. Am. Oil Chem. Soc. 33: 630-634

226 Kaunitz, H., C.A. Slanetz, R.E. Johnson, J. Guilmain, H.B. Knight, D.H. Saunders and D. Swern. 1956
Nutritional properties of the molecularly distilled fractions of autoxidized fats
J. Nutr. 60: 237-244

227 Kaunitz, H., R.E. Johnson and C.A. Slanetz. 1952
Rancid lard effect on rats fed complete and riboflavin-deficient diets
J. Nutr. 46: 151-159

* 228 Kawada, T., B.D. Mookherjee, and S.S. Chang. 1966
Chemical reactions involved in the catalytic hydrogenation of oils. III.
Further identification of volatile by-products
J. Am. Oil Chem. Soc. 43:237-241

229 Keith, R'W' and E'A' Day. 1962
Determination of the classes of free monocarbonyl compounds in oxidizing fats and oils
J. Am. Oil Chem. Soc.

* 230 Keppler, J.G., J.A. Schols, W.H. Feenstra and P.W. Meijboom. 1963
Components of the hardening flavor present in hardened linseed oil and soybean oil
J. Am. Oil Chem. Soc. 42: 246-249

231 Keys, A., J.T. Anderson, F. Fidanza, M.H. Keys and B. Swahn. 1955
Effect of diet on blood lipids in man
Clin. Chem. 1: 34

232 Kingsbury, K'J' C' Aylott, D'M' Morgan and R. Emmerson. 1961
Effects of ethyl arachidonate, cod-liver oil and corn oil on the plasma cholesterol level
Lancet i 739-741

233 Kinsell, L'W' G'D' Michaels, G'C' Cochrane, J'W' Partridge, J'P' Jahn and H'E' Balch. 1954
Effect of vegetable fat on hypercholesteremia and hyperphospholipidemia
Diabetes, N'Y' 3 113-119

234 Kinsell, L'W' J' Partridge, L. Boling, S. Morgen and G'D' Michaels. 1952
Dietary modification of serum cholesterol and phospholipid levels
J. Clin. Endocrinol. 12 909-913

235 Kirschenbauer, H.G. 1960
Fats and Oils, An Outline the Their Chemistry and Technology
Reinhold Publishing Corp., New York

236 Kishimoto, Y and N.S. Radin. 1964
Structures of the ester-linked mono- and diunsaturated fatty acids of pig brain.
J. Lipid Res. 5:98-102

237 Kishimoto, Y. and N.S. Radin. 1966
Determination of brain gangliosides by determination of ganglioside stearic acid.
J. Lipid Res. 7:141-145

* 238 Kishimoto, Y., N.S. Radin, W.W. Tourtellotte, J.A. Parker, and H.H. Itabashi. 1967
Gangliosides and glycerophospholipids in multiple sclerosis white matter
Arch. Neurol. 16:44-54

239 Kishimoto, Y., W.F. Davies and N.S. Radin. 1965
Turnover of fatty acids of rat brain gangliosides
J. Lipid Res. 6:525-531

240 Klenk, E. and K. Oette. 1960
The nature of C20 and C22 polyunsaturates occurring in the liver oils during the metabolism of linoleic acids by fats on a fat-free diet
Z. Physiol. Chem. 318 86-99

241 Klose, A.A.; Hanson, H.L.: Mecchi, E.P.; Anderson, J.H.: Streeter, I.V. and Lineweaver, H. 1953
Quality and stability of turkeys as a function of dietary fat
Poultry Sci. 32:82-88
Klose, A.A., H.L. Hanson, E.P. Mecchi, J.H. Anderson, I.V. Streeter and H. Lineweaver. 1953
Quality and stability of turkeys as a function of dietary fat
Poultry Sci. 32:82-88

242 Klose, A'A' E'P' Mecchi, H'L' Hanson and H. Lineweaver. 1951
The role of dietary fat on the quality of fresh and frozen stored turkeys
J. Am. Oil Chem. Soc. 28 162-164

243 Kohn, R., and J. Pokorny. 1962
Effect of the seasons and of soy oil supplements on the content of essential fatty acids in human milk (Czech)
Cesk. Gynek. 27:556-562

244 Korey, S.R. and A. Stein. 1963
Enzymic degradation of gangliosides
Life Sci. 3:198-203

* 245 Koritala, S. 1968
Selective hydrogenation of soybean oil. III. Copper-exchanged molecular sieves and other supported catalysts
J. Am. Oil Chem. Soc. 45:197-200

* 246 Koritala, S., and H.J. Dutton. 1965
Hydrogenation of linolenate. XII. Effect of solvents on selectivity
J. Am. Oil Chem. Soc. 42:1150-1152

* 247 Kritchevsky, D., S.A. Tepper, D. Vesselinovitch, and R.W. Wissler. 1971
Cholesterol vehicle in experimental atherosclerosis. Part II: Peanut oil
In, Atherosclerosis, Elsevier Publishihg Co., Amsterdam pp. 53-64

* 248 Kuemmel, D.F., and L.R. Chapman. 1966
Analysis of methyloctadecenoate and octadecadienoate isomers by combined liquid-solid and capillary gas-liquid chromatography
Anal. Chem. 38(11):1611-1614

249 Lambertsen, G., H. Myklestad and O.R. Braekkan. 1964
The determination and contents of alpha and gamma tocopherols in margarine
J. Food Sci. 29: 164-167

* 250 Lambertsen, G., H. Myklestad and O.R. Braekkan. 1971
Studies on monoene fatty acid isomers in hydrogenated fish oils.
J. Am. Oil Chem. Soc. 48:389-391

251 Laptew, A. 1932
Hydrierung von Sojabohnenol
Oel-Fett-Industrie 1:31-33

* 252 Lea, C.H. 1936
Antioxidants and the preservation of edible fats.
J. Soc. Chem. Ind. (Trans. and Comm.) 293T-302T

253 Lin, Tsung-Min, E. Karvinen and A.C. Ivy. 1955
Relation of dietary fat to absorption and elimination of exogenous and endogenous cholesterol
Am. J. Physiol. 183: 86

* 254 Loury, M. 1970
The evolution of vitamins in the technology of dietary oils and fatty materials (Fr.)
Ann. Nutr. Aliment. 24:B227-B246

255 Lundberg, W.O. 1961 and 1962
Autoxidation and Antioxidants
Interscience Publishers, New York
Vol. 1 and Vol. 2

289 Mattill, H.A. 1947
Antioxidants
Ann. Rev. Biochem. 16: 177-192

290 Mattson, F.H. and R.A. Volpenhein. 1961
The specific distribution of fatty acids in the glycerides of vegetable fats
J. Biol. Chem. 236: 1891

* 291 McCay, C.M., and H. Paul. 1937
The effect of melting point of fat upon its utilization by guinea pigs
J. Nutr. 15:377-382

292 McOsker, D.E., F.H. Mattson, H.B. Sweringen and A.M. Kligman. 1952
The influence of partially hydrogenated dietary fats on serum cholesterol levels
J. Am. Med. Assoc. 180: 380

* 293 Mecchi, E.P., M.F. Pool, G.A. Behman, M. Hamachi, and A.A. Klose. 1956
The role of tocopherol content in the comparative stability of chicken and turkey fat
Poult. Sci. 35:1238-1246

* 294 Meijboom, P.W. 1964
Relationship between molecular structure and flavor perceptibility of aliphatic aldehydes
J. Am. Oil Chem. Soc. 41:326-328

* 295 Melnick, D., C.M. Gooding, and H.W. Vahlteich (The Best Foods, Inc.). 1952
Soya bean oil compositions
U.S. Pat. 2,627,469 issued in 1952

296 Melnick, Daniel, and Arthur E. Waltking (CPC International, Inc.). 1970
Edible vegetable oil
U.S. Pat. 3,529,974 issued Sep. 22, 1970

* 297 Menzel, D.B., and H.S. Olcott. 1964
Positional distribution of fatty acids in fish and other animal lecithins
Biochim. Biophys. Acta 84:133-139

* 298 Merker, D.R. (Swift & Co.). 1957
Deodorization of hydrogenated fatty oils
U.S. Pat. 2,783,260 issued Feb. 26, 1957

* 299 Merker, D.R. (Swift & Co.). 1958
Non-selective hydrogenation of fats and oils
U.S. Pat. 2,862,941 issued Dec. 2, 1958

300 Metcalfe, L.D. and A.A. Schmitz. 1961
The rapid preparation of fatty acid esters for gas chromatographic analysis
Anal. Chem. 33: 363-364

301 Milas, N.A. and D.M. Surgenor. 1946
Studies in organic peroxides. VIII. t-Butyl hydroperoxide and di-t-butyl peroxide
J. Am. Chem. Soc. 68: 205

302 Miller, D., K'C' Leong, G'M' Knobl and E. Gruger. 1964
Exudative diathesis and muscular dystrophy induced in the chick by esters of polyunsaturated fatty acids
Proc. Soc. Exp. Biol. 116 1147-1151

303 Miller, D.S. and P.R. Payne. 1964
Dietary factors influencing nitrogen balance
Proc. Nutr. Soc. 23: 11-19

304 Miwa, T.K., K.L. Mikolajczak, F.R. Earle and I.A. Wolff. 1960
Gas chromatographic characterization of fatty acids. Identification constants for mono and dicarboxylic methyl esters
Anal. Chem. 32: 1739-1742

* 305 Miyake, R., Y. Shimamura, and H. Yajima. 1965
Kinetics of fat hydrogenation
Chem. Pharm. Bull. 13(7):843-858

306 Miyoshi, S. and M. Kurata. 1942
Studies of Diene. III. Adduct compound of beta eleostearic acid with acrolein
J. Chem. Soc. Japan 63: 1158-1159

307 Mohrauer, H. and R.T. Holman. 1963
Effect of linolenic acid upon the metabolism of linoleic acid
J. Nutr. 81:67-74

308 Mohrauer, H., K. Christiansen, M.V. Gan, M. Deubig and R.T. Holman. 1967
Chain elongation of linoleic acid and its inhibition by other fatty acids in vitro
J. Biol. Chem. 242:4507-4514

* 309 Mohrhauer, H. and R'T' Holman. 1963
The effect of dose level of essential fatty acids upon fatty acid composition of the rat liver
J. Lipid Res. 4(2) 151-159

* 310 Mohrhauer, H., and R.T. Holman. 1963
Effect of linolenic acid upon the metabolism of linoleic acid
J. Nutr. 81:67-74

* 311 Mohrhauer, H., K. Christiansen, M.V. Gah, M. Deubig and R.T. Holman. 1967
Chain elongation of linoleic acid and its inhibition by other fatty acids in vitro
J. Biol. Chem. 242(19):4507-4514

312 Moore, T. 1940
The effect of vitamin E deficiency on the vitamin A reserves of the rat
Biochem. J. 34: 1321-1327

313 Morin, R'J' S' Bernick, J'F' Mead and R'E' Alfin-Slater. 1962
The influence of exogenous cholesterol on hepatic lipid composition of the rat
J. Lipid Res. 3 432

* 314 Morris, C.E., and F.P. Khym (Armour and Company). 1945
Recovery of catalyst from hydrogenated oil
U.S. Pat. 2,602,807 issued in 1945

315 Mustakas, G.C., W.J. Albrecht, G.N. Bookwalter, V.E. Sohns, and E.L. Griffin, Jr. 1971
New process for low-cost, high-protein beverage base
Food Technol. 25(5):534-538, 540

316 Nason, A. and I.R. Lehman. 1955
Tocopherol as an activator of cytochrome c reductase
Science 122: 19-22

* 317 National Academy of Sciences, Committee on Nutritional Misinformation. 1973
Supplementation of human diets with vitamin E. A statement of the Food and Nutrition Board, Div. of Biol. Agr., National Research Council, Washington, D.C.

* 318 Neudoerffer, T'S' and C'H' Lea. 1966
Effects of dietary fish oil on the composition and stability of turkey depot fat
Brit. J. Nutr. 20 581-594

319 Ni, T.G. 1938
Further experiments on the prevention of nutritional encephalomalacia in chickens
Chin. J. Physiol. 13(3):229-238

* 320 Njaa, L.R., O.R. Braekkan, G. Lambertsen, and F. Utne. 1971
Hydrogenated marine fat, effect on growth and liver weight in young rats given a high fat, low protein ration
Nutr. Metabol. 13:207-221

321 O'Brien, J.S. and B.L. Sampson. 1965
Fatty acid and fatty aldehyde composition of the major lipids in normal gray matter, white matter and myelin.
J. Lipid Res. 6:545-551

356 Rotruck, J.T., A.L. Pope, H.E. Ganther and W.G. Hoekstra. 1972
Prevention of oxidative damage to rat erythrocytes by dietary selenium
J. Nutr. 102: 689-696

* 357 Roubal, W.T., and A.L. Tappel. 1966
Damage to proteins, enzymes and amino acids by peroxidizing lipids
Arch. Biochem. Biophys. 113:5-8

358 Saha, J.G., M.A. Nielsen and A.K. Sumner. 1970
Effect of commercial processing techniques on lindane- and DDT-14C residues in rapeseed oil
J. Agric. Fd. Chem. 18(1): 43-44

* 359 Sassoon, H.F. 1973
Time factors in obesity.
Amer. J. Clin. Nutr. 26:776-783

* 360 Sassoon, H.F., Y. Dror, J.J. Watson and B.C. Johnson. 1973
Dietary regulation of liver glucose-6-phosphate dehydrogenase in the rat: starvation and dietary carbohydrate induction
J. Nutr. 103:321-325

361 Schlenk, H. and J.L. Gellermann. 1960
Esterification of fatty acids with diazomethane on a small scale
Anal. Chem. 32: 1412-1414

362 Schlenk, H., J.L. Gellerman and D.M. Sand. 1962
Acylated cyclodextrins as stationary phases for comparative gas-liquid chromatography
Anal. Chem. 34: 1529-1532

363 Schmid, H.H.O., H.K. Mangold and W.O. Lundberg. 1965
Critical solution temperatures of aliphatic compounds I. Homologous and vinylogous fatty acids and methyl esters
Microchemical J. 9: 134-144

364 Schultz, H.W., Day, E.A. and Sinnhuber, R.O. 1962
Symposium on foods: Lipids and Their Oxidation
Avi Publishing Co., Westport, Conn.
Schultz, H.W., E.A. Day and R.O. Sinnhuber. 1962
Symposium on foods: Lipids and Their Oxidation
Avi Publishing Co., Westport, Conn.

365 Schwarz, K. 1965
Selenium and kwashiorkor
Lancet 1: 1335

366 Scott, M.L. 1962
Selenium.
In: Mineral Metabolism, ed., C.L. Comar and F. Bronner Academic Press, New York
Vol. 21B: 543-558

* 367 Scott, M.L. 1973
The Selenium Dilemma
J. Nutr. 103:803-810

368 Seher, A. 1969
Gemeinschaftsarbeiten der DGF, 52. Mitteilung. Neubearbeitung der "Einheitlichen Untersuchungsmethoden für die Fett- und Wachs-Industrie". XXXV: Analyse von Fettbegleitstoffen III.
Fette Seifen Anstrichm. 71: 833-837

369 Sergeev, A.G., et al. 1956
Installation for continuous hydrogenation of fats
U.S.S.R. Pat. 103,217, July 25

* 370 Silveira, A., Jr., Y. Masuda, and S.S. Chang. 1965
Chemical reactions involved in the catalytic hydrogenation of oils. II. Identification of some volatile by-products
J. Am. Oil Chem. Soc. 42:85-86

* 371 Simmons, Raymond O., Edward J. Reid, Alfred E. Blankenship, and Perry W. Hargan, Jr. (Hunt Foods and Industries, Inc.). 1968
Liquid shortening containing no solid dispersions and having improved low temperature properties
U.S. Pat. 3,394,014 issued Jul. 23, 1968

* 372 Sinclair, H. 1968
Soya-bean oil in myocardial infarction
Lancet 2:877

373 Sinclair, R.G. 1929-1930
Some observations on the growth of rats on "fat-free" and "fat- containing diets"
Proc. Soc. Exp. Biol. Med. 27: 1059-1062

374 Sinclair, R.G. 1932
The metabolism of the phospholipids. 5. The relationship between the amount of fat ingested and the degree of unsaturation of the phospholipids and neutral fat in the tissues of the rat
J. Biol. Chem. 96: 103-125

375 Sinnhuber, R'O' C' Yu and Te Chang Yu. 1958
Characterization of the red pigmen formed in the 2-thiobarbituric acid determination of oxidative rancidity
Food Resl 23 626

376 Skidmore, W.D. and C. Entenmann. 1962
Two-dimensional thin-layer chromatography of rat liver phosphatides
J. Lipid Res. 3: 471-475

377 Smith, H.A. 1955
Catalysis
P.H. Emmet, (Ed.), Reinhold Publishing Coporation, New York Vol. 3, 149

* 378 Smith, K.J., P.B. Polen, D.M. de Vries, and F.B. Coon . 1968
Removal of chlorinated pesticides from crude vegetable oils by simulated commercial processing procedures
J. Am. Oil Chem. Soc. 45:866-869

379 Sokol'skii, D.V. and E.G. Bolkhovitina. 1965
Low temperature hydrogenation of cottonseed oil on nickel-chrome catalysts
J. Am. Oil Chem. Soc. 33: 654

380 Spitzer, R.R., and P.H. Phillips. 1946
Soybeans--alopecia in rats fed certain soybean oil meal rations
Proc. Soc. Exp. Biol. Med. 63:10-13

381 Sreenivason, B. and J.B. Brown. 1956
Octa-decadienoic acids of shortenings and margarines
J. Am. Oil Chem. Soc. 33: 341

382 Sroczynski, A., K. Organisciak, J. Chojnowski. 1971
New chocolate base
Przem. Spozyw. 25(7):267-268

* 383 Stansby, M.E. 1967
Misconceptions about nutritional properties of fish oils
In, Fish Oils, M.E. Stansby (Ed.), AVI Publishing Co., Westport, Conn. pp. 283-288

* 384 Stansby, M.E. 1969
Nutritional properties of fish oils
In, World Review of Nutrition and Dietetics, Karger, Basel/New York 11:46-105

* 385 Stansby, M'E'. 1973
Problems discouraging use of fish oil in American manufactured shortening and margine
J. Am. Oil Chem. Soc. Accepted for publication

386 Stark, W. and D'A' Forss. 1962
A compound responsible for metallic flavor. I. Isolation and identification
J. Dairy Res.

387 Steenbock, H., H. Irwin and J. Weber. 1936
The comparative rate of absorption of different fats
J. Nutr. 12: 103-111

388 Stoffel, W. 1963
Der Stoffwechsel der ungesattigten Fettsauren, I. Zur Biosynthese hochungesattigter Fettsauren
Z. Physiol. Chem. 333: 74-88

* 389 Stout, V.F. 1968
Pesticide levels in fish of the Northeast Pacific
Bull. Environ. Contam. Toxicol. 3(4):240-246

* 390 Stout, V.F., F.L. Beezhold, and C.R. Houle. 1970
DDT residue levels in some U.S. fishery products and the effectiveness of some treatments in reducing them
FAO Technical Conference on Marine Pollution and Its Effects on Living Resources and Fishing, Rome, Italy, Dec. 9-18, 1970

391 Strain, H.H. 1942
Chromatographic Adsorption Analysis
Interscience Publishers, Inc., New York

392 Svennerholm, L. 1964
The distribution of lipids in the human nervous system
J. Neurochem 11:839-853

393 Swern, D. 1964
Bailey's Industrial Oil and Fat Products
Ed.3. Interscience, New York

394 Tappel, A.L. 1955
Studies of the mechanism of vitamin E action. 3. In vitro copolymerization of oxidized fats with protein
Arch. Biochem 54: 266-280

395 Thomasson, H.J. 1953
Biological standardization of essential fatty acids, a new method
Intern. Rev. Vit. Res. 25: 62-82

396 Thomasson, H.J. 1955
The biological value of oils and fats. I. Growth and food intake on feeding with natural oils and fats
J. Nutr. 56: 455-468

* 397 Thomasson, H.J. 1956
The biological value of oils and fats. IV. The rate of intestinal absorption
J. Nutr. 59(3):343-352

398 Thomasson, H.J. 1962
Essential fatty acids
Nature 194: 973

* 399 Thomasson, H.J., J.J. Gottenbos, J. Kloeze, and R.O. Vles. 1969
Nutritional evaluation of hydrogenated fats
Proc. Nutr. Soc. 25:1-4

400 Thor Lexow. 1933
Schmelzpunkte von Fettgemischen sowie Konsistenzbestimmungen bei Fett und Margarine (Norwegisch)
Bergen 64 S

401 Tidwell, H.C. and L.E. Holt. 1936
The estimation of the total lipids and the lipid partition in feees.
J. Biol. Chem. Vol 112, p. 605

* 402 Tsuchiya, T. and G. Akiyama. 1933
Re-esterification of fats with glycerol.
J. Soc. Chem. Ind., Jap. (Suppl.) 2:33B-34B

403 Turpeinen, O.J. 1938
Further studies on the unsaturated fatty acids essential in nutrition
J. Nutr. 15: 351-366

* 404 U.S. Department of Agriculture. 1972
Agricultural Statisics
Government Printing Office, Washington, D.C.

* 405 U.S. Pharmacopoieal Commission. 1960
U.S. Pharmacopoiea, 18th Edition
U.S. Pharmacopoieal Commission, Bethesda, Maryland

* 406 U'S' Bureau of the Census, Department of Commerce. 1971
U'S' Imports for Consumption and General Imports
Goverment Printing Office, Washington, D'C'
Publications FT 246-71, 246-69, 246-65

407 U'S' Department of Agriculture. 1959
Fatty acids in food fats
Home Economics Research Report, Washington, D'C'
No. 7

* 408 U'S' Tariff Commission. No date
Synthetic Organic Chemicals, U'S' Production and Sales
Government Printing Office, Washington, D'C'

* 409 Ueno, S. 1938
The relationship between thiocyanogen value and iodine value in the course of oil-hardening.
J. Soc. Chem. Ind., Jap. (Suppl.) 200B-202B

410 Uri, N. 1961
Physico-chemical aspects of autoxidation
In Autoxidation and Antioxidants, Interscience Publishers, New York

411 Vagelos, P.R. 1964
Lipid metabolism
Ann. Rev. Biochem. 33: 369

* 412 Van der Steur, J.P.K. 1961
Nutritional aspects of processing chemical additives on fats and oils
Fed. Proc. 20(Suppl. 7):217-223

413 Vandenheuvel, F.A. and D.H. Vatcher. 1956
Partition chromatography of aliphatic acids. Quantitative resolution of normal chain even acids from C 12 to C 24
Anal. Chem. 28: 838-845

414 Vilbushevitch, M'. 1912
Converting fat, fish oil, etc. into compounds of higher melting point by hydrogen and a catalyzer
U'S' Patent 1,024,758

415 Wakil, S.J. 1962
Lipid metabolism
Ann. Rev. Biochem 31: 139

416 Ward, R'J'. 1963
Sex differences in the alpha-tocopherol requirement of rats as shown by the hemolysis test
Brit. J. Nutr. 17 135

417 Waterman, H.I., L.J. Boelhouwer and L.J. Revallier 1951
Hydrogenation of fatty oils
Elsevier Publishing Co., New York p. 241

418 Wheeler, P., and F.R. Goetzl. 1947
Quantitative changes in plasma fatty acids of allergic and nonallergic individuals following single and repeated administration of soybean oil; preliminary report
Perm. Found. M. Bull. 5:63-65

419 Widmark, E.M.P. and H. Weymark. 1936
Ein Vergleich zwischen dem nahrungsphysiologischen Wert von Butter und Margarine auf Grund einer Zusammenstellung der diesbezuglichen Literatur (Schwedisch)
Arsskr. Alnarp. Malmo 48 S

* 420 Williams, L., and C. Carroll. 1973
Effects of dietary carbohydrate-fat combination on changes in lipid metabolism induced in rats by amino acid unbalance
J. Nutr. 103:991-998

421 Wolfrom, M'L' and G'P' Arsenault. 1960
Chromatographic separation of 2,4-dinitrophenylhydrazine derivatives of highly oxygenated carbonyl compounds
Anal. Chem. 32 693

422 Woodford, F.P. and G.M. Van Gent. 1960
Gas-liquid chromatography of fatty acid methyl esters: the carbon numbers as a parameter for comparison of columns
J. Lipid Res. 1: 188-190

* 423 Woods, W.D., E.L. McCune, and B.L. O'Dell. 1967
Toxicity of topically applied fats and oils
Proc. Soc. Exp. Biol. Med. 125:124-127

* 424 Wyatt, C'J' and E'A' Day. 1963
Autoxidation of fish oils.' II. Changes in the carbonyl distribution of autoxidizing salmon oils
J. Food Sci. 28 305-312

425 Zajcew, Mykola. 1968
Hydrogenation of fatty oils with palladium catalysts. VIII. Preparation of a cocoa-butter substitute
Engelhard Ind., Tech. Bull. 9(3):96-104

426 Zakim, D. and R.H. Herman. 1969
Regulation of fatty acid synthesis
Am. J. Clin. Nutr. 22: 200

427 Zakim, D., R.S. Pardini, R.H. Herman and H.E. Sauberlich. 1967
Mechanism for the differential effects of high carbohydrate diets on lipogenesis in rat liver
Biochim. Biophys. Acta 144: 242

* 428 Zemplenyi, T., Z. Lojda, D. Grafnetter, J. Fodor, and V. Felt. 1960
Effect of soy oil on experimental atheromatosis of the aorta and on certain enzymes in the vascular wall in rabbits (Czech.)
Cas. Lek. Cesk. 99:1346-1351

* 429 Zhukov, A.V., and A.G. Vereshchagin. 1969
Quantitative determination of phosphorus in soybean lipids
J. Lipid Res. 10:711-713

430 Zuckerman, L. and G'H' Marguardt. 1963
Muscle, erythrocyte and plasma electrolytes and some other muscle constituents of rabbits with nutritional muscular dystrophy
Proc. Soc. Exp. Biol. Med. 112 609